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STEEL.

(Continued from page 284.)

The third kind of Steel, or 3dly. CAST STEEL.

In cast iron, the carbon used, has never completely and uniformly metallized all the iron by uniting with the oxygen which gave it the form of an ore: also, the iron is in some parts united to carbon not merely to saturation, but beyond it; and not merely chemically, but mechanically. Iron may be greatly supersaturated or overloaded with carbon, as in the case of plumbago (Black-lead,) and in the smooth black-lead surface of kishy cast iron.

But in *steel*, the carbon seems chemically united to iron, and to a certain point encreases its fusibility; cast steel then, is a chemical combination of blistered steel, with a still greater proportion of carbon; which is communicated to it, by fusing the blistered steel, either in contact with charcoal, or with limestone and bottle glass. I have already observed that 100 grains of chalk or pure limestone will yield 44 or $44\frac{1}{2}$ grains of carbonic acid gas; which 44 grains of gas, contain somewhat better than $12\frac{1}{2}$ grains of pure charcoal or carbon.

These remarks will explain the following report of Guyton Morveau to the National Institute of July 4, 1798, on Clouet's method of making steel.

Account of the Experiments of Citizen Clouet, on the different states of Iron, and its conversion into Cast-steel.*

The learned reporter begins his account, by giving an historical sketch of the scientific and correct information we possess, respecting the art of steel-making. He states, that from the time when the labours of Reaumur had enlightened the practice of making natural steel, and steel by cementation, the theory remained stationary, notwithstanding the numerous and valuable experiments of Bergman, Rinmann, Priestley, &c. until the appearance of the excellent memoir of Vandermonde, Berthollet, and Monge, in the Memoirs of the Academy of Sciences for 1786. That the English, who had long supplied the European market with steel of cementation, remained also in the exclusive possession of the article known by the name of cast-steel, which, though confined to certain fine works†, is, nevertheless, a very valuable branch of national industry; that various experiments have been made with success, on a confined scale, in France, to imitate this product, since the time when Jars published an account of the method used at Sheffield; but that from a want of precision in the narrations of these processes, and the difference which is, with justice, considered to subsist between the experiments of the laboratory, and those of the manufacturer in his extensive operations, the art of making cast-steel was considered, by the most eminent French chemists, as very far from being publicly known: and Vandermonde, Monge, and Berthollet, notwithstanding their acquaintance with these facts, thought fit to declare,

* From the report of Citizen Guyton, made to the National Institute of France, on 16th Messidor in the year VI. (July 4, 1798) inserted in the Annales de Chimie, XXVIII. 19.

† It is used in a great variety of common tools and works in England.

in the public instructions drawn up by order of the committees of safety, that they could offer nothing but conjectures on the subject*. In this situation was the knowledge of the chemists and manufacturers of France, when Citizen Clouet resumed his experiments on a larger scale at the house of the Conservatory of Arts, and the mineralogical school at Paris, on the fusion of various kinds of steel, and the immediate conversion of iron into cast-steel.

On this subject, the author delivered a memoir to the Institute of France, which forms the subject of Guyton's report. He first treats of the combinations of iron and charcoal. One thirty-second part of charcoal is sufficient, as he affirms, to convert the iron into steel; one-sixth part of the weight of the iron affords a steel which is more fusible, but still malleable; and, after this term, it becomes nearer to the state of cast-iron, and no longer possesses enough of tenacity. By augmenting the dose of charcoal the fusibility is increased; and, at last, it acquires the state of grey cast-iron.

The particular cast-iron, which results from the combination of iron and glass, forms the second object upon which the attention of Citizen Clouet was fixed. The glass enters but in a small quantity into this compound, notwithstanding which, the properties of the mass are changed. This iron, though very soft to the file, if heated merely to cherry red, flies in pieces under the hammer: the cast ingot contracts greatly in cooling; and when, by careful management, it has been made into bars, the operation of hardening gives them the grain of steel, and renders them brittle, without adding to their hardness.

Charcoal in powder, added to the glass, changes the result, and increases the fusibility; but the nature of the product is greatly influenced by the dose of these ingre-

* Nichols. Phil. Journal II. 102.

dients. From one-30th to one-20th part of the iron, affords steel capable of a high degree of hardness, which may be forged at a low red heat, and has all the properties of cast-steel. If more charcoal be employed, the products resemble those of the smelting-furnace.

The attraction of iron for carbon, continues Citizen Clouet, is such, that at a very high temperature, it will take it even from oxygen. He proves this by the following experiments: Let iron, in small pieces, be put into a crucible with a mixture of equal parts of carbonate of lime and clay; let the heat be urged to the degree necessary to weld iron, and kept at that elevation for an hour, or more, according to the size of the crucible: the metal being then poured into an ingot mould, will prove to be steel of the same quality as cast-steel.

The oxydes of iron are equally susceptible of passing through the states of soft iron, steel, and fusible or cast-iron, according to the proportions of coal made use of. The black oxyde of iron, of which the state appears to be the most constant, becomes iron when heated in the crucible with an equal bulk of charcoal powder: a double quantity affords steel: a progressive augmentation, imparts the characters of the white and the grey cast-iron.

Lastly, Citizen Clouet observed the same transitions dependant on the respective quantities, by heating cast-iron, and the oxyde of iron; cast-iron and forged-iron; the oxyde of iron and iron; the oxyde of iron and steel. No more than one-fifth of cast-iron is necessary to convert bar-iron into steel.

Iron and its oxyde do not intimately unite together. The black oxyde, mixed with half the quantity of charcoal which would be necessary for its reduction, affords iron, which is soft, possessing little tenacity, of a black colour, and indistinct fracture.

One-sixth of oxyde, restores common steel to the state

of iron, by heating them together in the forge, or in the way of cementation.

At the end of his memoir, Citizen Clouet has given observations on the manner of producing cast-steel, and the furnaces proper for this effect.

He determines the nature of the fluxes, the degree of heat, the quality of the crucibles, the precautions for casting the ingot, the method of forging this kind of steel, the processes to be followed in experiments at the forge upon two kilogrammes of the materials, and the proportions to be given to a reverberatory furnace capable of heating four crucibles, each containing 12 or 13 kilogrammes of steel (about 28 pounds avoirdupois each crucible).

He remarks, that the mere ingredients of saline glass cannot be directly used in this process; that glasses, which are too fusible, render the steel difficult to forge; that steel, kept for a long time in fusion, takes up more glass than is proper; and lastly, that the melted matter must be stirred, and the glass carefully taken off before casting, in order to prevent its mixing with the steel.

The Commissaries of the Institute proceeded to repeat and verify the experiments of Citizen Clouet. These operations, which are related at length, were as follows. 1. Six hectogrammes (about 21 oz. avoirdupois) of filings of farrier's nails, and four of a mixture of equal parts of white marble, or carbonate of lime, and baked clay of an Hessian crucible, both reduced to powder, were well blended together, and exposed to the heat of a forge-furnace urged by three bellows-pipes for an hour and a half. The crucible failed at the first experiment; but, on repetition, a bar of steel was afforded. 2. Upon making the experiment with Macquer's furnace, the fusion was not complete, though the fire had been urged to 151° of Wedgwood. 3. In another excellent wind-furnace, 367 grammes (about 13 oz. avoirdupois) of small-drawn iron

nails, and 245 grammes (about 8½ oz. avoirdupois) of a mixture of carbonate of lime and baked clay, were exposed to strong heat for an hour, when the fusion was judged to be complete; and after removing the vitreous matter the ingot was poured out. From the effect produced on two pyrometric pieces, it was judged that the steel had undergone a heat of 150 degrees. This steel had all the properties of cast-steel, and was made into razors by citizen Lepetitoualle, who found it of a good quality, easy to be worked, and capable of bearing a comparison with the cast-steel marked *Marshal* and *B. Huntsman.*

Upon these facts, the reporter observes, that since iron does not become steel but by taking up about 0,2013 of its weight of carbon*, and in the present process it exists only in the form of carbonic acid, this acid must consequently be decomposed; which happens, as the reporter observes, by means of a combination between its principles respectively and certain adequate portions of the iron, that is to say, the oxygen of the acid combines with part of the iron, and forms an oxyde with which the vitreous flux becomes charged, and the carbon combines with the rest of the iron, and forms steel. Hence it may be inferred, that this new process must be attended with a loss of so much more consequence, as it is necessary to use iron of the best quality for making steel. But, on this head, the reporter takes notice that the loss in the experiment with the wind-furnace was not quite one-twelfth part; and, in another experiment, by Vauquelin, the loss was less than one twenty-second part; a loss, which he observes, will be well repaid by the increased value of the

* This quantity (upwards of one-fifth) so much exceeds any addition which iron is stated to gain by conversion into steel, that I suppose it to be 0,2013 in the centenary or hundred parts of iron. Iron is reckoned to gain about a little more than half a pound in the hundred weight by cementation.—3 Nich. Jour. quto. 134.

product, and may reasonably be expected to be still less in operations on a large scale. He thinks, moreover, that this new method may probably turn out of high value for producing steel of uniform quality with regard to the dose of carbon. For he thinks that this quantity, or proportion is likely to be determined by the equilibrium of the forces of affinity which cause the decomposition of the carbonic acid. Or, in other words, if we suppose an indefinite quantity of carbonic acid to be presented at an elevated temperature to a mass of iron not greater than could be converted by the dose of carbon contained in that acid, the iron will form two combinations, the oxyde and the steel; and it is conceived that the equilibrium between the attraction which tends to preserve the union of principles in carbonic acid, and those which are exerted between the iron and those principles will prove to be such that the carburet of iron will be formed precisely in those proportions which constitute good cast-steel. This subject, which certainly shews the acuteness of Citizen Guyton with regard to the doctrines of chemical attraction, must be decided by the test of experiment.

The report is concluded with a summary of the facts and observations it contains, together with an inference, that the immediate conversion of iron into steel, without using charcoal, is a great and valuable discovery with regard to the increase of national industry; that there is no doubt but the process will succeed in the large way, and that Citizen Clouet is entitled to a public recompence for his liberal, and unreserved communications.

That all the facts are of high value to science, and that the observation respecting the combination of vitreous matter with iron, as well as that which shews that carbonic acid can produce the steel conversion, are new and important, cannot be questioned; but whether the use of carbonate of lime and clay, which is attended with some

loss, may be preferable to vitreous flux and coal, which afford some small additional weight, is not yet as it should appear, decided by the actual operations."

These experiments of Clouet, were repeated by Mushet; who found that no mixture of limestone and clay, no fusion with lime alone, or with glass alone, in a *common* crucible, would convert iron into steel; though the properties of the iron were in some degree altered: but when the fusion took place in a *black-lead* crucible, steel was uniformly produced. Hence it may be reasonably presumed, that the carbon was furnished, not by the decomposed carbonic acid of the limestone, but by the black-lead mixed with the crucible; black-lead being a very highly carburetted iron.

These ideas were pursued by Mushet; who went through a course of trials on the fusion of pure malleable iron with charcoal alone in various proportions. As Mushet's experiments, have in my opinion, *settled* the theory of the formation of Steel, I shall give them at length.

On the different Proportions of Carbon which constitute the various Qualities of Crude Iron and Steel. By DAVID MUSHET, *Esq. of the Calder Iron Works.*

It is of considerable importance to the manufacturer to ascertain the absolute portion of charcoal which in his process becomes united with the metal to form cast iron. Having once admitted the fact, that it is in the ratio of the carbon presented to the metallic particles that he obtains a determinate quality of crude iron, experiment will enable him to deduce, that in manufacturing the richest natures of iron his produce from the ore will be more, by the extra quantity of carbon necessary to constitute this quality, than when the inferior numbers of iron are produ-

ced. In all cases, therefore, in making cast iron, considerable quantities of the coal become united with the iron, forming, by weight, a portion comparatively great.

From the usual processes hitherto employed in manufacturing blistered steel, the positive quantity of carbon which became united with the iron never became an object worthy of the attention of the manufacturer. It was sufficient to him that his bars possessed blisters sufficiently large and prominent to assure him that his steel was sufficiently converted. The unerring test of practice through a long series of operations confirmed the correctness of this deduction; and it must have appeared a matter of little importance to the formation of steel, that its direct operation of principle should be developed, or the laws which regulate its affinity in cementation.

No additional fact was necessary to the production of cast steel. The simple fusion of bar steel, regulated by such circumstances as practice, and the various uses to which this steel is applied, was all that was necessary to be known; the affinity of iron for carbon, and the various proportions in which it exists with the metal, forming the different qualities of steel, here met with no elucidation.

On the contrary, we still find that the union of iron and charcoal to form steel, is a matter of doubtful opinion among manufacturers, and the weight gained by its cementation generally denied.

It is only lately that a process has been brought into use for making cast steel, which has for its basis or principle the direct proportions of carbon necessary to form steel, illustrative at the same time of that beautiful phænomenon of affinity betwixt iron and carbon, which constitutes the endless varieties of this metal.

To investigate this subject with accuracy, it appeared to me that a series of experiments, made by the fusion of bar

iron with well prepared charcoal of wood in vessels completely air-tight, would be productive of the greatest nicety of result. With this view, the proportions of iron and charcoal recorded in the following experiments were each of them introduced into crucibles of Stourbridge clay while the clay was yet moist. The top was accurately closed upon the contents, and the crucibles set aside to dry for eight or ten days. Previous to the introduction into the melting furnace they were baked in a common annealing fire to bring them to an ordinary red heat: from this furnace, while hot, they were successively placed in the assay-furnace for reduction.

The following are the details of these experiments:

	Grains.
Exp. I. Pieces of Swedish iron - -	1173
Charcoal $\frac{1}{5}$, or - grs. $581\frac{1}{2}$	
The mixture was exposed to a moderate degree of heat for 70 minutes, when the crucible was withdrawn. When cold it was carefully examined, and found free from cracks.	
Charcoal untaken up, of a deep black colour,	$310\frac{1}{2}$
Charcoal disappeared in the fusion -	271
equal to 48 per cent. of the original quantity.	
The button obtained was supercarbonated crude iron, and weighed.	1233
Gained in weight, by the combination of carbon,	60

equal to $\frac{1}{19}$th part fully of the first weight of iron.

The fracture of this button was exactly that of No. I. pig iron, towards the upper surface largely granulated; and below a substratum of small grained metal resembling No. III. pig iron.

	Grains.
Total weight of the mixtures -	$1754\frac{1}{2}$

Charcoal remaining	310½ grains.	
Iron obtained -	1233 grains.	1543
	Total loss in fusion	211

The quantity of charcoal which disappeared in this operation was equl to $\frac{1}{4\frac{3}{10}}$ th part the weight of the iron.

	Grains.
Exp. II. Swedish bar iron - -	1093
Charcoal ¼, or - - grs. 273¼	

The fusion of this mixture was effected in fifty minutes. When cold, the crucible was found entire, and containing of charcoal not taken up 90¼

Lost in the fusion 183

equal to 67 per cent. of the original weight of charcoal. A fine button of supercarbonated crude iron was found, which weighed - 1143

Gained in weight by combination of charcoal 50

equal nearly to $\frac{1}{2\frac{1}{2}}$d part the weight of the iron employed. The fracture of this button was inferior in point of lustre and prominency of crystal. It was, however, similar to the usual run of the No. I. iron of the manufacturer.

The quantity of charcoal which disappeared in this experiment was equal to ⅛th part the weight of the iron.

	Grs.
The aggregate of the mixture weighed	1366¼
Charcoal remaining 90¼ grains.	
Iron obtained - 1143 grains.	1233¼
Lost in weight upon the whole	133

Exp. III. Swedish iron in pieces - - 1143

Charcoal ⅛th, or - grs. 190

This mixture was fused in thirty minutes, and was allowed to cool to a low red heat

before it was removed from the furnace. Grains.
When cold, the crucible was found without
cracks, and the charcoal not taken up weighed 55

Charcoal disappeared, equal to 71 per cent. 135
The metallic button now obtained was superbly carbonated so as to resemble a mass of carburet of iron. It weighed - - 1193
Original weight of the iron - 1143

Gained by combination of charcoal 50

equal nearly to $\frac{1}{23}$d part the weight of the iron. All the surface presented by this button was uniformly covered with a rich and lustrous coating of carburet, indicating a superior quality of crude iron. The quantity of charcoal which disappeared on this fusion was equal to $\frac{1}{48}$d part the weight of the iron employed.

The aggregate of mixture here weighed - 1333
Charcoal not taken up 55 grains.
Iron obtained - 1193 grains. 1248

Total loss in the melting 85

It is worthy of remark, that the loss of charcoal in these experiments, together with the general loss in fusion, diminish, in a series proportionate to the quantity of charcoal introduced, bearing no perceptible relation to the quantity of iron. The weight gained by the metallic buttons respectively, indicate nearly the same degree of saturation of the carbonic principle, whatever difference of appearance existed as to external appearance in No. III. It therefore appeared a matter of some curiosity, worthy of investigation, what became of the extra loss of carbon in Nos. I. and II. beyond that sustained in No. I. when the richest iron was produced.

Charcoal disappeared	No. I.	II.	III.	
Equal to - -	$\frac{1}{4\frac{3}{10}}$	$\frac{1}{6}$	$\frac{1}{8\frac{1}{2}}$	
Gained by iron - -	$\frac{1}{19}$	$\frac{1}{22}$	$\frac{1}{23}$	Average $\frac{1}{21\frac{1}{3}}$d part.
General loss in fusion	211	133	85	Grains.

Exp. IV. Swedish iron - - - 1060

Charcoal $\frac{1}{10}$th, or 106 grains.

From this mixture a very perfect fusion was obtained, in which all the charcoal disappeared except about grain$\frac{1}{2}$ composed of small granules possessing a rich deep black colour. The metallic button weighed 1093

Gained by the combination of charcoal 33

equal to $\frac{1}{33}$d part the weight of the iron employed. In addition to the weight of the button, the sides and top of the crucible contained a considerable number of minute spheres of iron possessing prismatic colours. The surface of the present product was crystalized in radii. The fracture was that of highly blown crude iron of a pale silvery white colour, marked with an imperfect crystallization. The quantity of charcoal which disappeared in this operation was equal to $\frac{1}{10}$th part the quantity of iron at first introduced.

	Grains.
The aggregate weight was - - -	1166
Charcoal remaining $\frac{1}{2}$ grain, and iron obtained 1060	$1060\frac{1}{2}$
Total loss in this fusion	$105\frac{1}{2}$

Exp. V. Swedish iron - - - - 1000

Charcoal $\frac{1}{15}$th, or - - - 66

This fusion was found complete after half an hour's exposure. The charcoal had totally disappeared. The metallic button was regularly crystallized, and weighed 1000 grains, being exactly the same weight introduced. Be-

sides the button, some thousands of metallic globules entirely covered the sides and concave top of the crucible. It was found impracticable to collect them all. By estimation they appeared to be from 15 to 20 grains. The fracture of this button was whitish blue, clear, and possessed a lustre similar to the fracture of zinc. An approximation to grain was visible, and, from minute comparison, a very early stage of steel was indicated.

	Grains.
The aggregate of the mixture weighed -	1066
Button of iron 1000, globules taken at 20, -	1020
Total loss in the fusion	46

Exp. VI. Swedish iron - - 1035

Charcoal $\frac{1}{20}$th, or - $51\frac{1}{2}$ grains.

The mixture yielded, by fusion, a metallic button partially crystallized, weighing - - 1032

Lost in fusion, equal to 312th part, 3

The charcoal had entirely disappeared. The fracture of this button displayed a very regular grain, similar to that of steel. In subjecting it to forging and other tests, it proved to be steel of a soft quality.

	Grains.
Original weight of mixture -	$1086\frac{1}{2}$
Iron obtained - - -	1032
Total loss in fusion	$54\frac{1}{2}$

Exp. VII. Swedish iron - - - 1055

Charcoal $\frac{1}{30}$th part, or 35 grains.

A very perfect fusion was obtained from this exposure. The metallic button was found beneath a covering of glass possessed of a white streaky surface, the mass of which was of the transparency and colour of a smoky topaz: it was found to weigh - 1052

Lost in fusion, equal to $\frac{1}{351}$th part the original iron 3

In this experiment, also, the charcoal had completely disappeared. The present product was minutely examined, but gave no indications of steel. After being deeply cut with a chisel, it was broken with very great difficulty across the anvil. It was then forged, and plunged hot into water; but did not harden. It generally resembled those qualities of iron obtained by fusion with earths and glasses. This experiment was repeated four times, and always attended with a similar result; so that it seemed deducible from it, that $\frac{1}{30}$th part of carbon in addition to any quantity of iron was insufficient to form steel; and, referring to the result of No. VI. it appeared that even $\frac{1}{20}$th part formed a steel much too soft for the general purposes of manufacture. This conclusion, however, being at variance with facts I had already established upon the formation of cast steel in common crucibles, was here inadmissible. It was therefore necessary to seek for an explanation of the phænomenon of the charcoal disappearing in close vessels, formerly alluded to, before any certain knowledge of the exact quantities of charcoal could be ascertained, which were necessary to form either cast iron or steel in vessels made impervious to the air. I uniformly remarked in the present experiments, that when the quantity of charcoal introduced was from $\frac{1}{30}$th to $\frac{1}{200}$th the weight of the iron, a portion of glass was constantly formed upon the surface of the metallic button. The quantity generally increased as the proportion of charcoal decreased; so that, in some experiments, 300, 350, and 400 grains of amber-colour glass was obtained. The The colour was blueish black, smooth in the centre but a little oxdated towards the edges. Its fracture presented close dark grey crude iron. The crystals much closer and more minute than in those experiments where richly carbonated crude iron was obtained. Appreciating its

upper surface of this glass was frequently of a pure pearly white colour. In one experiment, where $\frac{1}{70}$th of charcoal was used, I obtained a large quantity of glass cellular throughout. Each cell was surmounted upon the top with concentric circles of pearly lines, forming a curious and pleasing effect.

Having fully satisfied myself that operations performed in close vessels thus prepared were subject to uncertainty, arising as well from the formation of glass as from some unknown affinity exerted upon the charcoal; and having performed several experiments with well filled open crucibles, with charcoal alone, wherein I found little comparative loss, I performed a very accurate series of experiments, viz.

Having selected a parcel of well-prepared Stourbridge clay crucibles, with covers exactly fitting, I proceeded to make the following experiments upon the quantity of charcoal which forms crude iron and steel; first premising that both crucible and cover were brought to a bright red heat before the substances acted upon were introduced. This was done with the greatest possible caution, to avoid volatilizing any part of the charcoal, and rendering the result inaccurate. From the approximation of these results in repeating most of these experiments, I found that no material difference had occurred.

	Grains.
Exp. I. Swedish bar iron - -	885
Charcoal ,, or -	grs. 442
This mixture was exposed for half an hour, and a perfect button of supercarbonated crude iron was obtained. Along with the metal was found of intensely black charcoal not taken up -	290
Charcoal disappeared, equal to 34·4 per cent.	152
The metallic button now obtained was found to weigh	928

Gained in weight by the combination, equal to $\frac{1}{20\frac{1}{2}}$ grs.
part of the original weight of the iron - 43
Charcoal disappeared - - 152

Total loss in charcoal 109

Collective weight of the iron and charcoal originally introduced - - - grs. 1327
Iron obtained in the fusion grs. 928
Charcoal not taken up - 290
1218

Total loss in this experiment 109

Exp. II. Swedish bar iron - - 925
Charcoal one fourth part, or - grs. $231\frac{1}{4}$
This mixture, after a similar exposure, was completely fused. When cold, the crucible was found to contain of very fine charcoal $125\frac{1}{4}$

Charcoal disappeared in the fusion, equal to 45 per cent. - - - - 106
The metallic button was richly carbonated, and weighed - - - - - 972
Gained in weight by the union of charcoal, equal to $\frac{1}{19\frac{9}{10}}$th part of the original weight of the iron, - - - - 47
Charcoal disappeared - - - 106

Lost in fusion 59

Collective weight of iron and charcoal originally introduced - - grs. $1156\frac{1}{4}$
Iron obtained in the fusion grs. 972
Charcoal not taken up - $125\frac{1}{4}$
1097

Total loss in this experiment 59

		grs.
Exp. III. Swedish bar iron		915
Charcoal $\frac{1}{8}$th, or	grs. 152	
This mixture was subjected to a similar heat, and a perfect fusion effected. There was found of charcoal not taken up	65	
Charcoal disappeared, equal to 57 per cent.	87	
The metallic button resembled the produce of No. I. and II. and weighed		960
Gained by the fusion, equal to $\frac{1}{20\frac{3}{10}}$th part the first weight of the iron		45
Charcoal disappeared		87
Lost in the fusion		42
Collective weight of the iron and charcoal used		1067
Iron obtained	grs. 960	
Charcoal remaining	65	
	1025	
Total loss in this experiment		42
Exp. IV. Swedish bar iron		977
Charcoal one eighth, or	grs. 122	
This mixture entered into fusion in nearly the same time as the former. There was found on the surface of the metal a portion of very beautiful carbon, which weighed	40	
Lost of charcoal in fusion, equal to 67 and 2 tenths per cent.	82	
The metallic button obtained in this experiment was superbly carbonated, and apparently formed an entire mass of carburet. It weighed		1020
Gained in weight by the union of carbon, equal		

			grs.
to 22 and four tenth part the first weight of the iron			43
Charcoal disappeared			82
		Lost in the fusion	39
Original weight of the mixture		grs. 1099	
Iron obtained	grs. 1020		
Charcoal remaining	40		
		1060	
		Total loss in this experiment	39
Exp. V. Swedish bar iron			1125
Charcoal one ninth, or		grs. 122	
From this fusion was obtained a supercarbonated button of crude iron, upon the surface of which was found of fine charcoal			25
Lost of charcoal, equal to 80 per cent.			97
Compared with the former results, the metal now obtained was inferior in point of carbonation. Its surface was smooth, and of a dull lead colour; entirely free from the usual shining specks of carburet which very rich crude iron contains upon its surface. It weighed			1168
Gained in fusion, equal to one 26th part the weight of iron employed			43
Charcoal disappeared			97
		Loss in the fusion	54
Collective weight of the mixture		grs. 1247	
Weight of metallic button	grs. 1168		
Charcoal not taken up	25		
		1193	
		Total loss in this experiment	54

		grs.
Exp. VI. Swedish iron - - -		880
Charcoal one twelfth or -	grs. 73	
This was sufficiently heated to produce fusion. When cold, there was found upon the surface of the metal a portion of very black charcoal weighing - - - -	12	
Lost in the fusion, equal to 83 and a half per cent.		61
The metallic button possessed a uniformly smooth surface, partially covered with carburet, and weighed		920
Gained by the combination of charcoal, equal to one twenty second part - - - -		40
Collective weight of the mixture originally introduced - - -	grs. 953	
Charcoal not taken up -	grs. 12	
Iron obtained - -	920	
	932	
Lost in the fusion		21
Charcoal disappeared -	grs. 61	
Iron gained in weight -	40	
Total loss in this experiment		21

From the results of these experiments it becomes obvious that bar iron may be converted into the finest qualities of crude iron by the addition of any portion of charcoal from one half to one twelfth part its weight: that in passing from the malleable to the carbonated crude state, it uniformly gains in weight by a combination of carbonaceous matter equal to $\frac{1}{20\frac{1}{2}}$, $\frac{1}{19\frac{9}{10}}$ th, $\frac{1}{20\frac{3}{10}}$ th, $\frac{1}{22\frac{4}{10}}$ th, $\frac{1}{26}$th, $\frac{1}{22}$d: average $\frac{1}{21\frac{8}{10}}$th part its own weight.

It is here again worthy of remark, that in all these experiments with open vessels, a portion of charcoal disappeared always in proportion to the quantity introduced, and not analogous to the quantity of iron.

Disappeared of Charcoal	Iron gained.
When one half was used, 34·4 per cent.	$\frac{1}{20\frac{1}{2}}$th, part.
When one fourth was used, 45 per cent.	$\frac{1}{19\frac{1}{10}}$th part.
When one sixth was used, 57 per cent.	$\frac{1}{20\frac{3}{10}}$th part.
When one eighth was used, 67·2 per cent.	$\frac{1}{22\frac{4}{10}}$th part.
When one ninth was used, 80 per cent.	$\frac{1}{26}$th part.
When one twelfth was used, 83·5 per cent.	$\frac{1}{22}$d part.

Upon the whole, if the results of these six experiments, performed in open vessels, are compared with the three first detailed in last communication, where a similar quality of crude iron was obtained in vessels perfectly close, no material difference will be found. They mutually support each other, as to the quantity of carbon necessary to form crude iron, while they still leave in doubt the cause of the disappearance of the charcoal in close vessels. In the case of open vessels, it is highly probable that a considerable portion of the charcoal is destroyed before the heat of the furnace is sufficiently strong to lute the cover of the crucible.

This still, however, leaves unexplained, why, in experiment I. a loss of 152 grains of charcoal is sustained; while in No. VI. the original quantity introduced did not amount to half that quantity, yet 12 grains of the latter was found entire resting upon the surface of the reduced metal. The thickness and capacity of the crucible in both cases, and, indeed, all these experiments, were nearly alike.

The fact of malleable iron being convertible into the most carbonated state of crude iron, either in close or open vessels, where a portion of the carbonaceous matter was found reposing upon the surface of the newly-changed metal, creates some doubts as to the existence of oxygen in

crude iron. If it be admitted that bar iron is destitute of oxygen, which it is highly probable is the case; if a portion of this iron be introduced and fused along with a portion of carbonaceous matter in a vessel impervious to air, which vessel is found, when cold, to be more than half filled with charcoal, protecting a metallic button of crude iron below; it is with the greatest difficulty we can admit of the presence of oxygen in the metallic mass. It may be urged, that charcoal, considered as an oxyd of carbon, might impart a partion of oxygen to the metal. This must suppose, however, a continual action and reaction of affinity, wherein it is presumable the carbon would finally prevail, and carry off the oxygen. I conceive it more just to suppose, that what quantity of oxygen was contained in the charcoal, would be discharged by the latter deoxydating itself analogous to its superior affinity, rather than combining with the iron.

It is a fact well known amongst manufacturers, that cast iron of a silvery white fracture may be saturated to excess with carbonaceous matter simply by cementing it in contact with charcoal. In this process it acquires a soft grey fracture, easily reducible by the file. If this cast iron originally contained oxygen, a long cementation in contact with charcoal, most likely, would deprive it of this; yet we find it still possessed of all the properties of cast iron. From this we should be apt to conclude that oxygen at least is not necessary to the production of crude iron.

Again, in the process of cementation, bar iron is first changed, by a comparatively small dose of carbon, into steel. If this steel, by accident or intention, be continued somewhat longer in the furnace under an increased temperature, an excess of affinity is established betwixt the metal and the charcoal without the presence of a third principle: the steel becomes gradually more and more carbonated: it changes its fracture of granulation, if I may be

allowed the term, from that peculiar to blistered steel, through all those breaks peculiar to the respective qualities of crude iron ; and may at last pass into the state of a carburet of iron totally different in its properties and appearance from either steel or crude iron. This process may be carried on to the utter exclusion of atmospheric air; and here, if the process is stopped in its proper stages, will be found all the various qualities of crude iron formed without perfect fusion, where we cannot conceive oxygen to have existed.

I am aware of adducing circumstances from these experiments, at variance with the present received opinions upon the constituent parts of cast iron, and also in opposition to principles which I have formerly laid down. I wish not the present hints to be considered as assertions. As irreconcileable in some degree with former opinions, I wish they may lead to an ample investigation of the subject. The distinction hitherto made betwixt crude iron and steel, particularly by the French chemists, has been, that crude iron was the metal imperfectly reduced, but that the latter was iron perfectly reduced, combined with a small portion of carbon. The fact, however, of malleable iron passing into the state of fine crude iron without the contact of an oxygenous body, puts it upon a similar footing with steel, only altered by a greater comparative quantity of carbon. This reduces us to the necessity of drawing one of the two following conclusions: that steel is, equally as crude iron, a combination of iron, carbon, and oxygen ; or, that crude iron differs from steel only in the proportion of the carbon with which it is saturated.

Exp. VII. Swedish bar iron - grs. 1174
Charcoal $\frac{1}{15}$th part, or 78 grs.

A fusion was obtained from this mixture, after which there remained only a small portion of char-

grs.

coal, too minute for weighing.

The metallic button weighed - - 1213

Gained in weight by the combination of charcoal 39
equal to $\frac{1}{30}$th part the weight of the iron.

Weight of the iron 1174, and charcoal 78,= 1252
Weight of the button - - - - 1213

Total loss of weight in the fusion 39
equal to that gained by the iron. Upon minute inspection, no part of the surface of this button was carbonated. The colour was blueish black, smooth in the centre but a little oxidated towards the edges. Its fracture presented close dark grey crude iron. The crystals much closer and more minute than in those experiments where richly carbonated crude iron was obtained. Appreciating its real quality by comparison with crude iron manufactured for sale, it occupied that rank generally known by the names of No. II. grey melting pig iron.

Exp. VIII. Swedish bar iron - - grs. 922
Charcoal $\frac{1}{20}$th part, or 46 grs.
From the exposure of this mixture there resulted a very perfect metallic button whose upper surface presented a partial degree of radiated crystallization.
It was found to weigh - - - 950

Gained in weight by the combination of carbon 28
equal to $\frac{1}{33}$d part the original weight of the iron. The fracture of this button was smooth, silvery white, occasionally studded with carbonaceous specks in the form of small grains, an exact resemblance to mottled pig iron. In this experiment there remained not the most distant trace of carbonaceous matter. A small portion of amber-coloured glass was formed round the edges of the metal.

	Grains.
Weight of the iron 922, charcoal 46, = -	968
Metal resulting - - -	950
Total loss of weight	18
Exp. IX. Swedish bar iron - -	1330
Charcoal $\frac{1}{25}$th part, or 53 grs.	
From this mixture a perfect fusion and metallic button was obtained, which weighed -	1351
Gained in weight by the combination of carbon	21

equal to $\frac{1}{61}$d part the weight of the iron. In this experiment also the charcoal had completely disappeared. The upper surface of the button was smooth, the under surface considerably pitted. The concaves chequered with a rude crystallization peculiar to cast iron. The fracture of this metallic mass was bright silvery white, destitute of grain, and exhibiting a very perfect streaky crystallization slightly radiated. Its resemblance was strikingly similar to that of highly blown cast iron prepared in the finery for the purposes of bar iron making; an operation commonly in use for the purpose of decarbonating the iron, that it may, in the subsequent process, sooner pass into the state of malleability. The weight of iron and charcoal in the experiment amounted to grs. 1383

Iron obtained - -	1351
Total loss in the fusion	32
Exp. X. Swedish iron - -	1348
Charcoal $\frac{1}{30}$th, or 45 grs.	
From this proportion of mixture in half an hour a perfectly fused button of metal was obtained, which was found to weigh - -	1359
Gained in weight by the combination of carbon	11

equal to $\frac{1}{122}$d part the original weight of the iron. The upper surface of this button was smooth without configuration. Below the surface was uneven, and covered with minute but perfect crystallization. Its fracture was blueish silvery white, composed of flat dazzling crystals, proceeding in lines from a centre to the edges of the button. Here it was most obvious, that from the smallness of the proportion of carbon presented to the iron, the resulting product was found assuming the earliest stage of granulation approaching to the steely state. The brilliant concretions observable in the surface of the button were too indistinct and flat for steel capable of withstanding the hammer.

	Grains.
The joint weight of the iron and charcoal amounted to	1393
Iron obtained - - - -	1359
Total loss of weight in the fusion	34

Exp. XI. Swedish iron - - 1502

Charcoal $\frac{1}{40}$th, or 37 grs.

The metallic button obtained by the fusion of this mixture weighed - - -	1505
Gained in weight by the union of carbon	3

equal to $\frac{1}{500}$th part the first weight of iron. The upper surface of this button was smooth, with a faint impression of a chequered crystallization. The under surface possessed some large pits similarly though more perfectly crystallized.

The fracture possessed one shade of blue beyond that of No. X. A regular granulated surface composed of flat oblong crystals was observable, still too indistinct and too much on edge for workable steel. The weight of charcoal and iron in this experiment amounted to grs. 1539

Metal obtained - -	1505
Total loss of weight in the fusion	34

Exp. XII. Swedish iron - - grs. 1537
Charcoal $\frac{1}{50}$th, or 31 grs.
From the exposure of this mixture, a metallic button was obtained, which weighed - 1533

Lost in fusion, equal to $\frac{1}{384}$th part 4

The surfaces of this button were uniformly smooth. The fracture was dense, and displayed a grain peculiar to highly saturated blistered steel. When put under the hammer, with a low red heat, it stood a few blows, but afterwards parted. Weight of mixture employed in the experiment grs. 1568
Steel obtained - - 1533

Total loss of weight 35

Exp. XIII. Swedish iron - - 1362
Charcoal $\frac{1}{90}$th, or 15 grs.
A very fine fusion was produced from the exposure of this mixture. The metallic button was found to weigh 1319

Lost in fusion, equal to $\frac{1}{31\frac{6}{10}}$th part, 43

This button presented a wavy crystallized surface. The under surface was rough, and contained one large pit accurately crystallized. The fracture was regularly granulated, small, but distinct, of a light blueish colour. The crystals, though distinct, were not so prominent as those of easy drawing cast steel. It, however, hammered with the usual degree of caution necessary to the working of cast steel. The bar of steel formed from the button possessed all those properties requisite for file making, and other purposes requiring a quality highly charged with carbonaceous matter.

	Grs.
Weight of the mixture - -	1377
Steel obtained - - -	1319

	Grs.
Loss of weight in this experiment	58
Exp. XIV. Swedish iron - -	1372
Charcoal $\frac{1}{100}$th, or 14 grs.	
The button obtained weighed -	1312
Lost in the fusion	60

equal to $\frac{1}{22\frac{8}{10}}$th part the original weight of the iron. The surface of this button was smooth, without crystallization. The under surface rough, and possessed of one large pit in the centre, faintly marked with the usual crystalline appearance. The fracture presented regular light blue grains distinct, and more prominent than No. XIII. One-half of the button was drawn into a neat square bar, and proved steel of an excellent quality. One end of the bar being loose and shaled, welded tolerably well, and hardened afterwards with a low heat. In appreciating the quality of this result, it appeared to be that kind of steel suitable for penknives, razors, &c. possessed of neither the extremes of hardness nor of softnesss.

Beyond the proportion of $\frac{1}{100}$th part of charcoal to iron, I continued the experiment till the proportion was reduced to $\frac{1}{200}$th part. It would appear tedious to detail these experiments, the most interesting being already minutely described. In the same progressive manner, by diminishing the dose of carbon, the metallic result approached more and more to the softness of malleable iron, though by no means possessed of all its properties. In this series of experiments, iron presented with $\frac{1}{120}$th part its weight of charcoal was found to form very soft steel fit for making scissars, &c. which, in a good workman's hands, would have doubled, welded, and formed a very perfect point, afterwards hardening so as to display a beautiful close break of steel. By using the following precaution, it was even found capable of welding perfectly to

iron. Two flat bars of a similar shape, one of this quality of steel, and one of good malleable iron, were put under the hammer with a good welding heat. After a few light blows, the junction was completely made. The united bars were allowed to cool without further hammering till the shade of heat was bright red. The whole piece was then drawn out in a solid compact form, whose fracture, when cold, presented a complete junction of the iron and steel, exhibiting at the same time their respective grains.

When iron is presented in fusion to $\frac{1}{140}$th or $\frac{1}{150}$th part of its weight of charcoal, the resulting product occupies a kind of middle state betwixt malleable iron and steel. It then welds with facility, and, provided the precaution formerly mentioned is attended to, may be joined either to iron or steel, at a very high welding heat. Thus combined with carbon, it is still susceptible of hardening a little, but without any great alteration in the fracture. It possesses an uncommon degree of strength and tenacity, capable of an exquisite degree of polish, arising from its complete solidity and the purity of fracture conveyed to it by fusion.

When the dose of carbon is further diminished, and in the ratio of this diminution, the same steel or iron becomes more and more red short, and less capable of cohesion under a welding heat, so that, when the proportion is reduced to $\frac{1}{200}$th part the weight of the iron, the quality resulting is nearly analogous to the fusion of iron *per se*, or that obtained by the fusion of iron and earths.

It will appear evident from the result of these and former experiments, that crude iron and steel only differ from each other in the proportions of the carbon they contain. In thedetails now before us, charcoal alone is used in addition to the malleable iron as pure as is ever made, to effect every principal stage or modification of the metal. Hence we conclude, that

Iron semi-steelified is made with, charcoal, $\frac{1}{150}$th part.
Soft cast steel, capable of welding, with, $\frac{1}{120}$th
Cast steel, for common purposes, with, $\frac{1}{100}$th
Cast steel requiring more hardness, with, of charcoal, - - - $\frac{1}{90}$th part.
Steel capable of standing a few blows, but quite unfit for drawing, - - $\frac{1}{50}$th
First approach to a steely granulated fracture, is from - - - $\frac{1}{30}$th to $\frac{1}{40}$th
White cast iron - - $\frac{1}{25}$th
Mottled cast iron - - $\frac{1}{20}$th
Carbonated cast iron - - $\frac{1}{15}$th
And supercarbonated crude iron - $\frac{1}{12}$th, or when any greater quantity is used.

Although this is the quantity of charcoal necessary to form these various qualities of metal by this mode of synthesis, yet we are by no means authorized to conclude that this is the proportion of real carbonaceous matter taken up by the iron, seeing that in experiments No. I. to No. VI. inclusive, the weight gained by the iron was upon the average equal only to $\frac{1}{21\frac{9}{10}}$th, part; whereas the charcoal which disappeared in the different fusions amounted to 61. 1 per cent. of the original quantity introduced along with the iron.

In the succeeding experiments the following differences are remarkable:

No. VII.	Charcoal used.	$\frac{1}{15}$th	- Iron gained	$\frac{1}{36}$th	part.
No. VIII.	-	$\frac{1}{20}$th	- -	$\frac{1}{33}$d	
No. IX.	-	$\frac{1}{25}$th	- -	$\frac{1}{63}$d	
No. X.	-	$\frac{1}{30}$th	- -	$\frac{1}{122}$ $\frac{1}{2}$	
No. XI.	-	$\frac{1}{40}$th	- -	$\frac{1}{300}$th	
No. XII.	-	$\frac{1}{50}$th	- Iron lost	$\frac{1}{384}$th	
No. XIII.	-	$\frac{1}{90}$th	- -	$\frac{1}{36}$ $\frac{6}{10}$th	
No. XIV.	-	$\frac{1}{100}$th	- -	$\frac{1}{32}$ $\frac{8}{10}$th	

From this we see that when a proportion of charcoal equal to one fortieth part, and above, the weight of the iron is used, the latter always gains in weight; but when a more sparing proportion is introduced, room is left for the exertion of another affinity upon the metal, and it consequently and invariably loses in weight proportioned to the diminution of the carbon. I have here further to remark upon the foregoing experiment, and upon the nature of experiments by synthesis performed in this way in general, that the results as to quality will differ materially when different portions of matter are used. So that an operator repeating the above experiments either in crucibles smaller or larger, or with a greater or less weight of mixture, would not obtain the same results.

The formation of cast steel in the large way, founded upon the results of the foregoing experiments, affords an incontestable proof of this. In fusions of 18, 22, and 25 lbs. of iron each, we are obliged to increase the dose of carbon considerably beyond that requisite in small experiments. To form steel equal to that obtained in experiment XIII. wherein one ninetieth of charcoal was used, one fifty-fifth part is requisite to be introduced. For steel similar to that in experiment XIV. one sixty-fifth and one seventieth part are used. For softer steel one ninetieth, whereas in the small experiment 1 one hundred twentieth part was sufficient. If in the manufacturing a small extra quantity of carbon is requisite, this is saved by the comparatively small loss sustained in the transmutation of the iron into steel.

Many instances have occurred in the first fusion from a cast steel pot in the large way, where 25lbs. of iron, and its requisite proportion of carbon, not exceeding one seventieth, have afforded an ingot of cast steel weighing 24lbs. 12, 13, 14, and 15 ounces, being a loss equal to no more than 1 one hundred tenth, 1 two hundredth, 1

three hundredth, 1 four hundredth part the weight of the iron, whereas in experiments No. XIII. and XIV. the loss of metal amounted to one 31 six tenth, and one 22 eight tenth part the weight of the iron.

I shall conclude this paper with a few remarks upon the state in which carbon exists in steel and in crude iron.

When malleable iron is fused with 1 one hundredth thirtieth or 1 one hundred fortieth part of its weight of carbon, the resulting product is considerably steelified. The fracture is lighter in the colour than it formerly was in the state of iron. When fused with an 80th to 1 one hundredth, steel of an ordinary quality is produced, the fracture of the metal still becoming whiter. When the dose of carbon is increased beyond this, the steel becomes so hard and dense as to be unfit for hammering. The fracture now will be found approaching to the colour of silver, and losing its granulated appearance, assuming, however, a crystallized form. In this state the metal will be found to resist the hammer and file, and to be unfit for any purpose. Increase, however, the quantity of carbon to one twelfth or one fifteenth, the resulting product is no longer destitute of grain, nor possessed of the same degree of hardness. The fracture will be found grey, and the surface easily reduced by the file. A further increase of the carbon is accompanied by an increase of these properties. At 1-8th or 1-6th, the filings of the metal, when thrown into water, leave a carbonaceous pellicle covering the whole surface, and of a considerable thickness.

Thus we find that carbon hardens iron till it arrives at the highest pitch of density, which is indicated by the metal losing grain, and assuming a crystallized silvery fracture. At this point or maximum we may conceive that the respective proportions of mixtures are so nearly balanced that the affinity exerted by the iron is just sufficicient to deoxydate the charcoal, and that hitherto nothing

but pure carbon similar to the diamond has combined with the iron. If, however, the equilibrium is destroyed by a larger portion of charcoal, then we find the affinity too weak to deoxidate the whole, and part of it unites in the state of an oxide of carbon; at first constituting a mottled fracture, and afterwards, as the dose is increased, all those deepening blueish grey shades peculiar to soft cast iron. Hence carbon or its oxide again softens iron. It never, however, restores the properties of forging or of hammering. One invariable law, however, is maintained, that the fusibility of iron under every circumstance and modification is in the ratio of the quantity of carbon united."

In consequence of these experiments, Mr. Mushet took out a patent for the manufacture of cast steel, which is couched as follows.

Account of Mr. MUSHET'S *new Method of making Steel of various Qualities.*

"For this invention Mr. Mushet* has obtained his Majesty's royal letters patent; and, certainly, few discoveries of so much importance to this country have been made for a number of years past. The manufacture of cast steel, which has hitherto been tedious and expensive, is now reduced to a process of a few hours; and the quality of the article at the same time so much improved, as to be applicable to many purposes to which steel of the common manufacture cannot be applied. We shall not, however, dwell on the utility of the invention, but lay before our readers an account of it, extracted from Mr. Mushet's specification, which will speak more to an intelligent mind than would a volume of eulogium.

* Mushet's experiments have certainly thrown great light on the theory of steel; but I do not know whether his patent has been extensively used, or his steel compared with Huntsman's. T. C.

" The general principles of my process or processes are the fusion of malleable iron, or of iron ore, in such manner, and by such means, as immediately to convert them into cast steel; and, likewise, in certain cases, the after cementation of this steel to give it malleability, and the property of welding, in order to fit it for such purposes as require steel possessing these properties. These principles can be acted upon for the production of the various qualities of steel in a variety of ways; but the principle of my invention, and the mode of operation, may be fully understood by the examples which I shall adduce, and which will enable any person to perform the same, and to vary and alter the mode of operation according to his intention, and the particular quality of steel he may wish to manufacture.

" Thus, cast steel may be made by taking any convenient quantity of malleable iron, according to the size of the furnace and crucible or crucibles to be employed, and introducing it into the crucible or crucibles along with a proper proportion of charcoal, charcoal dust, pit-coal, pit-coal dust, black lead, or plumbago, or of any substance containing the coally or carbonaceous principle; but, in general, charcoal, pit-coal, or pit-coal cokes, especially if prepared in the manner hereinafter described, will be found to answer best. For this process not only bar iron may be employed, but also what is commonly called scraps, or waste iron: but, when the latter is used, a little more carbonaceous matter must be added to the mixture, to revive the rust, or oxide of iron, adhering to the scraps. The mixture in the crucible or crucibles must then be put into a furnace capable of giving a sufficiently intense degree of heat to run down or fuse the mixture, which must then be poured out into bar, ingot, or other moulds, according as the manufacturer intends to produce bars or ingots, or various articles or utensils that are

or may be, made of cast steel; for the whole iron, by fusion with the charcoal or other substances or things containing carbonaceous matter, will be found to have passed into the state of cast steel. If cast into bars or ingots, and a proper quantity of charcoal, or other substances or things containing carbonaceous matter, has been employed, such bars or ingots will be found in a state ready to take the hammer, and to be drawn or rolled into other shapes, according to the intention of the manufacturer. In some cases, especially where a heavy charge is to be run down, the crucibles must be previously properly disposed in the furnace, and the mixture introduced into them afterwards.

"By the process before described, and which may be varied with circumstances by any prudent operator, cast steel may be made in a few hours, which, by the process or processes hitherto discovered, has usually required many days, and sometimes weeks; for cast steel, by the common method of manufacture, has been hitherto made from bar steel, which had previously required, for its own conversion into that state, from the state of bar-iron, or of scrap-iron, a tedious cementation with charcoal, in a furnace constructed for the purpose, and usually known among manufacturers by the name of a *converting furnace*.

"It cannot here escape observation, that this is not the only saving in point of time and expense, gained by my process or processes; for, when I meet with or procure iron-stones or iron-ores sufficiently rich, and free from foreign mixtures, I save even the time and expense necessary for the conversion of such iron-stone or iron-ore first into cast or pig-iron, and afterwards by a tedious and expensive process, accompanied with a great waste of metal, into bar-iron. For such ore or iron-stones, being previously roasted or torrified, when that process may be found necessary, which will often happen, may be substituted for the bar-iron, scrap or waste iron, as before described,

and the result will be cast-steel, if a proper quantity of charcoal, charcoal-dust, pit-coal, pitcoal-dust, plumbago or black lead, or of any substance containing carbonaceous matter, has been used.

"For the common and ordinary qualities of cast-steel, a much smaller quantity of carbonaceous matter is requisite in the mixture than perhaps could have been suspected before my invention. When charcoal from wood is employed, a seventieth to a ninetieth of the weight of the iron will generally be found sufficient. When the quantity of the carbonaceous matter or principle exceeds one seventieth, and is increased to from one sixtieth to one fortieth or more of the weight of the iron, the steel becomes so completely fusible that it may be run into moulds of any shape, and be capable afterwards of being filed and polished. Hence by casting may be constructed stoves, grates, kitchen utensils, many kinds of wheels and mill works, a great variety of small machinery, and many other articles, which could not be so made by the processes now in use, and which way of making such articles constitutes a part of my invention.

"By my process various kinds of steel, differing as much from each other in their qualities as the various kinds of pig or cast-iron differ from each other, can be formed by merely varying the proportion of carbonaceous matter. Cast-steel of the common and ordinary qualities is too volatile when in fusion to admit of being run into any shape except straight moulds of a considerable diameter; but steel of such density as to admit of being cast into any form may be produced by my process, by increasing the quantity of charcoal, or matter containing the carbonaceous principle, and then fusing the mixture as before directed. When I wish to produce qualities of steel softer than is usually manufactured by the common processes, I find it best to use a small proportion of charcoal, some-

times so little as a two hundredth part of the weight of the iron. Steel produced with any proportion of charcoal, not exceeding a hundredth, will generally be found to possess every property necessary to its being cast into those shapes which require great elasticity, strength, and solidity. It will also be found generally capable of sustaining a white heat, and of being welded like malleable iron; and, indeed, as the proportion of charcoal or other carbonaceous matter is reduced, the qualities of the steel will be found to approach nearer to those of common malleable iron.

"By further pursuing the principle of my new invention, I fuse down malleable bar or scrap-iron in a crucible or crucibles, without any visible addition of carbonaceous matter, and run it into bar, ingot, or other moulds. In this state the metal is nearly of the same quality as when put in, only altered by the combination of a small portion of carbonaceous matter, which the iron by its chemical affinity attracts from the ignited fuel, or from the ignited carbonic gas of the furnace, and which enters by the mouth or through the pores of the crucible or crucibles, probably dissolved in caloric at a very high temperature. But whether so dissolved or not, the fact is, that a portion of the carbon passes from the fire into union with the iron, and thereby converts it into an extremely soft steel.

"Besides the different modes of operation above specified, I further reduce iron-ore, bar-iron, or scrap-iron, by the addition of lime or chalk, or other carbonats, or of carburets, with clay, glass, and other fluxes, in various proportions, and form all the various qualities of steel formerly enumerated.

"If the various kinds and qualities of steel obtained by the process or processes above mentioned be introduced into the common converting or other steel furnaces, in contact with carbonaceous matter, or with earths, and heat-

ed for five days, or more or less, according to the thickness of the bars or other forms, and the quantity introduced, the bars, ingots, or other shapes, being then taken from the furnace, will be found to possess all the solidity which they formerly were possessed of as cast-steel, with that property of welding peculiar to blistered, faggot, or german steel of the usual mode of manufacture.

"By this invention I obtain steel which for solidity may be used for the purposes of cast-steel; uniting at the same time the property of welding, without destroying the solidity or quality of the metal: a circumstance of the highest importance to our manufacturers. Ingots, bars, plates, and every shape into which this steel is cast, rolled, or hammered, will be possessed of uniformity of quality, without those numerous reeds, flaws, blisters, and disjoined laminæ found in steel made by the processes in use before my invention.

"When pit-coal cokes are to be used in any of the foregoing operations, either in mixture with the ore, or with the iron, or for fuel in the furnaces, in which the crucibles containing the mixture are exposed to the action of the fire, it is of the utmost importance that the cokes be properly prepared. The process which I have found to answer best for this purpose, though common cokes will also do, is founded upon the principle, that all access of oxygen to the coals to be coked, should be prevented: this end is gained by preparing the cokes in iron vessels, in the same manner as wood is now charred for the purpose of being employed in the manufacture of gun-powder. The bitumen, or coal-tar as it is commonly called, which is volatilized from the coals to be coked, by the heat applied to the exterior of the iron vessel or other chamber containing the said coals is thus saved, instead of being burnt or dissipated in the atmosphere, as is the case in the common process of coking, in which the coals are

exposed to combustion in open heaps, and which also partially, though in a less degree, takes place in the process commonly known by the name of Lord Dundonald's process for preparing coal tar."

Notwithstanding Mushet's experiments fully support his theory, that steel, is pure iron united to pure carbon, and that the various kinds of steel, depend the various proportions of the carbon united to the iron, yet I am persuaded that neither in the making of cemented steel, or of cast steel, or of case hardening, do the manufacturers confine themselves to the charcoal of wood. I have before observed, that the carbon united to animal charcoal, is more easily disengaged than that which is contained in vegetable charcoal, so that for case hardening, the charcoal of hoofs, horns, bones, clippings of leather, &c. is constantly and almost exclusively preferred. We sadly want a set of experiments, shewing the effect of treating iron in a crucible with equal weights of animal and vegetable charcoal—iron enveloped with Prussian blue, and exposed to a continued heat in a close crucible of common crucible clay: for the Prussic acid is always contained in animal charcoal.—Iron so treated with ammonia or volatile alkali, and its carbonats—and another series of experiments in addition to those of Mushet, on the different results in black lead crucibles and common crucibles. Such experiments would throw new light on the theory of the combination of steel and charcoal, and of course on the practice of making steel.

Until these are made, I think I may venture for various reasons to state it as probable, that in the making of blistered and german steel, the bars are imbedded by some manufacturers in a mixture of well burnt charcoal of wood, with about one sixth of animal charcoal made from hoofs, horns, leather cuttings, &c. also, that in making of cast steel, out of the clippings of blistered steel, german steel, old files, &c. these articles are fused with limestone and bot-

tle glass, either in a black lead crucible, or in a common crucible with a small proportion of lamp-black, or the soot of train oil.

In making cast steel, I understand there is uniformly a loss: in making blistered steel, there is a gain of about half a pound in the hundred weight, which in some measure designates the quantity of carbon taken up by and united to the iron in manufacturing steel of cementation.

The charcoal in a steel furnace, is generally so much exhausted as not to answer for a second cementation; that is in point of profit.

The principal characters of steel are the following.—It becomes harder on being made red hot, and then suddenly quenched in cold water.—It takes a much higher polish than iron, with a light grey, not a blue cast or hue—If a drop of dilute nitric acid (aqua fortis mixed with three times its bulk of water) be put upon clean steel, and after a minute, washed away without being wiped off, it leaves a black spot, because although the acid will dissolve the iron, it will not dissolve the charcoal. The same acid leaves no such black spot when dropt on clean iron: only a slight grey tinge—Steel can be made much more elastic than iron: a steel sword may be bent in a vice from heel to point, and when let loose will suddenly regain its former shape; it is more sonorous than iron; its grain, or fracture, is finer than that of iron; it expands by heat more than iron; it can be beaten into thinner plates than iron; it acquires magnetic power more slowly, but retains it longer than iron; red hot steel, quenched in cold water, retains two thirds of its red-heat bulk, but iron on being so treated, contracts to its original size previous to heating; steel heats quicker, and fuses much more easily than iron; on being fused and cast, it retains the property of malleability, except at a white

heat; polished steel is sooner tinged by heat, and with higher colours than iron. This is supposed to be a partial oxydation of the surface of the metal, but as it can take place under melted lead, or hot mercury (or hot oil) not exposed to the air, this explanation is doubtful; in a calcining heat, it suffers less by burning than iron, but by repeated heating and hammering with exposure to air, the charcoal or carbon can be gradually burnt away; the same effect takes place by gradual, long repeated hammering alone; in a calcining heat, a light blue flame hovers over steel, probably owing to the gradually burning of its carbon; in a white heat exposed to the bellows, it sends off more, and brighter, and lighter-coloured sparks than iron; when covered with powdered charcoal pressed down close upon it, and exposed to a strong heat, it becomes overloaded with carbon, and acquires a slight coat resembling; and indeed consisting of black lead (Kish.) when hammered, its specific gravity is somewhat greater than iron; it leaves a residuum of black charcoal when dissolved in acids, which pure malleable iron does not. The sulphureous acid is better for the purpose than the sulphuric.

Highly carbonated cast iron differs from steel, in as much as the texture and quality of the metal is not uniform. Cast iron is scarcely malleable; it is much more brittle than steel; it is but slightly hardened or softened by heating and cooling; it is fusible in a close vessel at 130 of Wedgewood's pyrometer; the black residuum on solution in acids, is more abundant in cast iron than in steel; cast iron contains uncombined carbon, and unmettalized iron; it is more sonorous than steel.

All these properties are owing to the superior quantity of carbon or charcoal, that is united to it, partly mixed and partly in combination.

I cannot better close this collection on iron and steel, than by Dr. Aikin's Summary.

Manufacture and properties of Steel.—Steel combines the fusibility of cast iron with the malleability of bar iron, and further possesses this very valuable property, that when heated and suddenly cooled, it becomes intensely hard, and is therefore much superior to simple iron for all kinds of cutting instruments, files and various other tools. In the present section we shall describe the different methods of preparing and tempering steel, reserving for the next section an enquiry into the chemical composition of this useful substance.

The most ancient way of making steel is probably that related by Agricola. Take some highly carburetted bar iron, cut it into small pieces and mix it with pulverized scoriæ, put the mixture into a crucible lined with charcoal, and bring it to a state of fusion in a blast furnace. When both the iron and scoriæ are thoroughly fluid, immerse in this metallic bath, four lumps of bar iron, weighing about thirty pounds each, and let them remain in this situation during five or six hours, stirring the bath occasionally with an iron rod; by this time they will have become soft and spungy, upon which they are to be taken out and drawn down into bars by the forge hammer. As soon as this is performed, the bars still hot, are to be plunged into cold water, by which they will be rendered brittle, and are then to be broken under the hammer into short pieces. The crucible in the mean time is to be replenished with the same mixture as before; and when its contents are become quite fluid, the pieces into which the bars have been broken, are to be again immersed till they become soft: each piece being then taken out and forged separately into a slender bar, is to be cooled while yet glowing hot, in cold water, and the process is finished. The above method is we believe entirely obsolete, though with a few

modifications that are sufficiently obvious, it would in all probability be found highly advantageous.

The *native* steel of Eisenhartz in Stiria has always been in high estimation since the eighth century, and is prepared directly from the ore nearly in the same manner as common bar iron. The ore made use of, is the Spathose Ironstone, consisting of the carbonats of iron, manganese and lime, together with a mixture of clay: it is procured in vast abundance from the neighbouring hill of Arzberg, and care is taken not to use any that has not been exposed for several years to the action of the air. No flux of any kind is necessary, and the fuel, which is charcoal, does not on an average exceed in weight one fifth of the ore. When a sufficient quantity of melted matter is collected at the bottom of the furnace it is let out into a deep mould, where it remains quiet a few minutes to allow the scoriæ to rise to the surface: this being done, a little water is sprinkled over it, which hardens the scoriæ and renders them easily removable: a second but much thinner crust of scoriæ generally succeeds, which is got rid of in the same manner. A little water is now thrown on the melted metal itself, by which its surface is suddenly covered with a congealed crust about an inch thick; this is removed, and by repetitions of the same process the greater part of the mass is thus converted into these irregular plates: what remains is a mass in the state of half malleable iron. These plates are transferred to the crucible of a refinery which has been previously lined with charcoal, and are covered with scoriæ and brought to a state of fusion, carefully observing however not to direct the blast from the bellows into the crucible, lest the iron should be decarbonized. After the whole has been in quiet fusion for some time, the fire is slackened, and as soon as the metal has congealed the scoriæ still fluid are let off. The mass is then subjected to a second fusion in the re-

finery with the same precautions as at first, and is now sufficiently purified to be forged: it is accordingly extended under the hammer and cut into bars which are examined by their fracture, and separated according to their qualities, into hard steel, soft steel, and steely iron; the latter is reserved by itself and used for pointing ploughshares and other coarse work; but the others are made up into packets, observing to place the hardest steel on the inside, which are then drawn into bars at a lower heat than that required for iron, and then the process is compleat. Thus the whole art consists in purifying the cast iron, taking at the same time particular care that the carbon which it contains, is not burnt away. If the original cast iron is very highly carbonized, it sometimes happens that the steel retains too large a proportion of carbon, which is evinced in the refinery by its being more easily fusible, and requiring a longer time to become solid again than usual: this defect however is speedily remedied, by adding iron filings or scraps of bar iron, the quantity of which is regulated by the degree of fusibility to be corrected.

If the manufacturer wishes to procure iron from this ore instead of steel, the only difference required in the treatment, is to get rid of nearly the whole of the combined carbon by roasting the plates in a reverberatory furnace before they are brought to the refinery, and by avoiding to line the crucible of the refinery with pounded charcoal. The iron thus produced is of an excellent quality.

The best of the Swedish and Norwegian ores are occasionally wrought into steel of a very good quality by nearly the same process of manufacture, provided in the smelting a larger proportion than usual of charcoal has been employed, to ensure a highly carbonized metal.

The usual method of converting iron into steel is by *cementation*. For the purposes of manufacture, this is performed on large quantities at a time in the following

manner. A cementation or converting furnace, consists of two parallel troughs, constructed of fire-brick, sufficiently long to admit with convenience a common bar of iron; these troughs rest upon a long grate from which flues proceed so as to distribute the heat as evenly as possible to every part: an arched vault is thrown over the top, and the whole is inclosed within a cone of masonry as the glass house furnaces are. The bars of iron intended for cementation are of the very best quality, (in England none but the Swedish Oregrund iron is employed for this purpose) and are carefully examined to ascertain that they are quite free from cracks, flaws, and every appearance indicative of their not being completely malleable. The requisite selection being made, a stratum of coarsely bruised charcoal is laid at the bottom of the cementing trough, upon which is arranged a layer of iron bars: to this succeeds another of charcoal, and so on till the trough is nearly filled, observing that the upper as well as the lowest layer is charcoal: it is then covered with a mixture of hard rammed clay and sand in order to exclude the air. A trough thus charged will contain from seven to ten tons of iron. The fire being lighted, the heat passes into the flues and raises the temperature of the troughs to a glowing red which is maintained for the space of from seven to eleven days according to the quantity of iron. At the extremity of each trough is a small hole, through which two or three bars project a few inches in order that they may be occasionally withdrawn to ascertain the progress of cementation: when by the trial bars, it appears to be compleat, the fire is put out, and after the troughs are sufficiently cool they are emptied of their contents. The form of the bars thus converted, remains unaltered, but their surface is covered over with bubbles or blisters, whence the steel in this state is called *blister steel:* it is heavier than the iron from which it was made

on account of its having absorbed a portion of carbon from the charcoal with which it was in contact, though this is by no means the only action that takes place in the process of steel-making, as we shall show in the next section. Blister steel is employed only for the coarsest purposes, such as pointing horses shoes, ploughs, and other agricultural instruments, &c. By being drawn down into smaller bars under the tilt-hammer, its texture is considerably improved, and it is known in the markets by the name of *tilted steel.* As repeated hammering improves iron, so it does steel: hence if a bar of highly carbonized blister steel, be broken into very short pieces, and these being formed into small packets, are again welded together and drawn down into bars, which being again doubled together are welded and tilted, repeating the process two or three times, the result will be a very material improvement in compactness and toughness, and the metal will be found well qualified for swords and the larger articles of cutlery: this steel has long been prepared in high perfection in Germany, whence it is called *German steel;* it is also known by the name of *Shear steel.*

This is the proper place to mention the process of *Case-hardening*, which in fact is only an imperfect kind of cementation, converting little else than the immediate surface of the metal into steel, and therefore being performed not on the rough bar, but the manufactured article. The cements or carbonaceous substances used on this occasion are bone shavings or turnings, horn cuttings, and old leather shoes. The work intended to be cased, having been previously filed to the requisite shape, that there may be as little occasion as possible to apply the file afterwards, is laid together with the cement in a pan of plate-iron. A forge fire is then made of considerable size, and when the upper part has caked together it is carefully lifted off without breaking, the pan is laid upon the red coals and covered with the caked mass. In this state it remains for near-

ly two hours, without urging the fire. Small pieces of iron wire that have been previously introduced into the pan being withdrawn from time to time, are dipped while hot in cold water, and by the file and the character of the fracture, the progress of the cementation is determined. When the intended degree of carburation is obtained, the fire is increased and the articles as soon as sufficiently heated are taken out of the pan and plunged in cold water. The inferior kinds of table-knives and some surgical instruments, where a considerable degree both of toughness and hardness is required, are prepared in this way.

The finest kind of steel however, called *English cast steel*, yet remains to be mentioned. It is commonly prepared by breaking to pieces the blister steel and then melting it in a crucible with a flux composed of carbonaceous and vitrefiable ingredients. When thoroughly fused it is cast into ingots, which by gentle heating and careful hammering are tilted into bars. By this process the steel becomes more highly carbonized in proportion to the quantity of flux, and in consequence is more brittle and fusible than before; it is inferior to the other kinds of steel in being incapable of welding either with iron or steel, but on the other hand surpasses them all in uniformity of texture, hardness, and closeness of grain, hence it is the material of all the finest articles of English cutlery. The composition of the flux used in preparing this steel is kept a secret among a few manufacturers, and in consequence, various experiments have been instituted both here and elsewhere to discover either the same or an equally successful method of making this beautiful substance. In 1795, Clouet published the results of some valuable experiments, from which it appears that by simply fusing bar iron with charcoal, a cast steel may be obtained more or less carburetted, according to the proportion of charcoal employed, and therefore possessing at pleasure in

greater or less degree the qualities of fusibility, brittleness, and hardness; he also showed that the same effects may be produced by fusing bar iron with glass and charcoal, or the black oxide of iron with the requisite proportion of charcoal alone, or by keeping in fusion for about the space of an hour a mixture of small bits of iron and equal parts of clay and marble or any other calcareous carbonat. In 1800, Mr. Mushet took out a patent for preparing cast steel of various qualities by fusing bar iron with different proportions of charcoal, coinciding (?) for the most part with the facts and principles before laid down by Clouet, and confirmed by his own experiments; but whether the steel thus prepared is equal to the finest cast steel of Huntsman, has not, we believe, been as yet completely ascertained.

Steel is rendered hard by heating and then suddenly cooling it. The degree of hardness which it is capable of acquiring is in direct proportion to its fusibility, or in other words to the quantity of carbon with which it is combined; and the degree of hardness which in any particular instance is actually given to it, is in proportion to the difference of temperature between the medium in which it is heated and that in which it is cooled; modified however by the capacity for heat, and the conducting power of the cooling medium. Thus if steel is heated somewhat below the degree at which it melts and then transferred into oil at the temperature of 200°, the hardness thus acquired will be inferior to that which would have been obtained if water, or still more so if mercury, at the same temperature had been made use of. Again, if instead of oil at 200° the same fluid at 400° had been employed, a greatly superior degree of hardness would have been produced.

The hardness acquired by this method has generally been thus accounted for. The particles of the metal by

being heated are placed at a greater distance from each other than before, and in proportion as this heat is again abstracted, the attraction subsisting between them will become efficacious, and they will approach nearer to actual contact; but the impetus with which this takes place will be in proportion to the difference of temperature, and therefore when red-hot steel is plunged in ice-cold mercury, the force or resilient spring of its particles will be greater than if mercury at 200° had been made use of, and consequently its hardness will also be greater. But this theory however ingenious is opposed by certain facts which perhaps may be found more consonant with the following explanation of them.

If we take the specific gravity of a piece of steel both when hardened, and after it has been softened by heating again and gradually cooling, we shall find that its bulk in the former case is greater than in the latter; whereas if the hardness of steel was owing to the rapidity and energy with which its particles collapsed on cooling, directly the reverse of this ought to take place, the state of greatest hardness should be that of the greatest specific gravity. So in like manner we find to be the case with glass; if a little of this in a melted state is dropped into cold water it will prove very hard and brittle; but if the same piece is again heated red (without however in any degree softening it) and afterwards allowed to cool gradually, its specific gra vity will have very notably increased, and it will have become tough and elastic. We may therefore consider the hardening of steel to be caused by the contemporaneous expulsion of part of its heat and the fixation of its particles before they have had time to arrange themselves and contract upon each other. Hence on the impression of any external force, the particles that are struck are not able to slide on each others surfaces, and thus distribute the impetus which they have received over the contiguous

ones; or in other words the mass becomes *harder* than it was before, hence also the whole force of a blow is borne by a comparatively small number of insulated particles, and these entirely giving way before a degree of percussion that might easily be sustained by the whole when combined, thus produce the quality of *brittleness*.

If highly carburetted steel is made nearly as hot as it can bear without melting, and is then plunged in very cold water, it is apt to fly to pieces, and even if this does not take place, the metal is not applicable to any use in this state of extreme hardness, for the particles are placed so far asunder, that the whole has a strong tendency to become crumbly, and will not bear a fine, even, sharp edge. In the practice of the best manufacturers, the hardening heat even for files, which are the hardest of all steel instruments, is not greater than a red visible by day-light; and all cutting and elastic instruments require to be much softer. The various degrees of hardness necessary for different articles are not however given, as might at first be supposed, by the simple process of hardening at the requisite temperature, but by the compound method of first giving to every article nearly a file hardness, and then, by the subsequent process of *tempering*, reducing the hardness to the particular degree necessary for each article.

Tempering consists in softening hardened steel by the application of a heat not greater than that which was employed in hardening it; for this purpose it is gradually heated more or less according to the temper required, and cooled again either gradually or rapidly, this making no difference; after which the steel is found to be softened or tempered exactly in proportion to the heat which it has undergone. While the steel is tempering, its surface displays a succession of colours (supposed to arise from a commencing oxydation) in proportion as it becomes

more and more heated, which the workmen in this metal have ingeniously taken advantage of, as indicating and serving to denominate the degree of temper required for different articles. The first perceptible colour is a light straw yellow, and this being produced by a small degree of heat indicates the highest or hardest temper; to this succeeds a full yellow, then a brown, afterwards a reddish blue, then a light blue, and lastly a full deep blue passing into black, which being the other extremity of the series, denotes the lowest degree of temper, and a hardness only a little superior to what the piece of steel would have acquired if when heated for the purpose of being hardened it had been allowed to cool gradually instead of being plunged into a cold liquid. The old method of tempering, and which indeed is still practised by most manufacturers, is to lay the articles on a clear coal fire, or on a hot bar, till they exhibit the requisite colour; but small articles which were to be reduced to a blue temper were commonly *blazed*, that is they were first dipped in oil or melted grease, and then held over a fire till the oil became inflamed, and thus evaporated.

Some particular articles require a nicety of temper that is not very easily attained by trusting merely to the change of colour, a circumstance that induced Mr. Hartley, in the year 1789, to take out a patent for a new and more accurate method. For this purpose a mercurial thermometer graduated as high as 600° is to be immersed in an iron trough heated by a furnace or lamp placed below it, and filled with fusible metal, upon the surface of which the steel is to be laid, which may thus be tempered with great accuracy at any degree of the thermometer that the artist chuses. Oil may be substituted to the fusible metal, and the effect will be the same, except that the steel being in this case tempered beneath the surface of the liquid, and of course out of the contact of atmospherical air,

will not exhibit those changes of colour which take place when the other methods are employed. The following table shows the temperature at which the various colours make their appearance.

430° to 450° indicates the several tints of straw colour, and is the temper for razors and those intruments which have a stout back supporting a keen and delicate edge.

470° corresponds with the full yellow, and is the proper temper for scalpels, pen-knives, and other fine-edged instruments.

490° indicates the brown yellow, and is the proper temper for scissars and small shears.

510° indicates the first tinge of purple, and is the temper for pocket and pruning-knives.

530° indicates purple, and is the temper for table and carving-knives.

550° to 560° indicates the different shades of blue, and is the temper for watch-springs, swords, and all those instruments in which great elasticity is required.

600° corresponds with black, and is the lowest degree of temper.

One great advantage attending the use of cast steel is its uniform quality: the carbon which it contains appears to be equally distributed through every part of the same mass in consequence of the fusion that it has undergone: whereas both the natural steel and the steel of cementation, are apt to contain veins of iron, either quite soft or at most very slightly carburetted, and thus a degree of imperfection and uncertainty is introduced extremely mortifying to the artist, and not unfrequently the occasion of much labour in vain. It is therefore no small benefit which Mr. Nicholson has conferred on the workers in iron and steel by publishing a simple and effectual method of ascertaining whether any particular bar is pure iron or steel or a mixture of both. The surface of the metal being cleaned

with a file or with emery paper, is to be spread over with very dilute nitrous acid, by which the iron will be dissolved, but the carbon will remain behind untouched; after therefore the acid has been allowed to act for a few minutes, the bar is to be put into clean water and moved about in it gently, that both the residual acid and the nitrat of iron may be washed away, care being taken not to touch the surface with the hand or any thing else that may rub off the carbon. The bar thus washed, if pure iron, will exhibit an uniform iron-grey colour; if it be pure steel, the colour of the surface will be black, the iron having been taken up by the acid and a thin coating of carbon remaining; but if it be a mixture of iron and steel, the surface will be dotted or streaked, those parts which are steel being of a dull black, and those which are iron exhibiting the usual colour and lustre of this metal.

Steel being considerably more expensive than iron, it is customary in making the larger and coarser kinds of cutting instruments to form only the edge of steel. The two bars of iron and steel are first welded together and afterwards forged into the requisite shape in the usual manner. Highly carbonized steel is however incapable of being thus united to iron, because the same temperature at which iron welds freely, is that, at which this kind of steel enters into fusion, and therefore the first stroke of the hammer will entirely shatter the steel and disperse it about in small fragments. This however is a difficulty which it is well worth while taking some pains to overcome, as the efficacy and durability of instruments thus composed materially, depends upon the goodness of the steel. The most effectual way hitherto discovered of uniting together iron and highly carbonized steel, is that published by Sir Thos. Frankland. The iron is to be raised to a welding heat, in one forge, and the steel is to be made as hot as it can bear without becoming very brit-

tle, in another; both pieces are then to be quickly brought to the anvil and made to adhere together by gentle hammering.

Several curious pieces of work are made of iron and steel welded together, especially the real Damascus sword blades, which are believed to be composed of slips or thin rods of iron and steel bound together with iron wire, and the whole firmly cemented together by welding. The properties and external appearance of such a blade, correspond very exactly with the supposed mode in which it is manufactured. Its colour is a dull blueish grey, it is scarcely harder than common steel from the forge, it is not easily bent, and when bent has no elasticity to recover its original figure; but the circumstance which principally characterizes it is the appearance of narrow waving lines not crossing each other and chiefly running from heel to point; they are ill-defined and about the thickness of a harpsichord wire. This wavy appearance is not produced by any perceptible indentation of the surface, but merely by a slight difference in the degree of polish or brightness, and therefore may be at once distinguished from the false damasking or etching by which other sword-blades are made to resemble the genuine Damascus ones. In the false Damascus blades, the waving lines, called the *water*, are obliterated by grinding, but in the real ones, although the water is at first imperceptible after grinding, yet it may at any time be made to re-appear by rubbing the blade with lemon juice, no doubt on account of the unequal action of this weak acid on a surface composed both of steel and iron.

Besides the varieties of steel that we have already described, there yet remains one more, concerning which a few words will be necessary: this is Wootz. The substance known by this name in India, is imported into this country in the form of round flat cakes about five inches

in diameter and one inch in thickness. When cold it is uncommonly refractory, neither breaking nor bending under the hammer. It is not nearly so easy to be filed as either bar or cast steel before these have been hardened: it takes an extremely high brilliant polish; its fracture is moderately close, resembling that of blister-steel that has been heated and hammered a little. When nearly white hot it is malleable, but is much more likely to crack under this treatment than even cast steel; it requires therefore much care, labour, and time to fashion it into any required shape. When made white hot, it exhibits the glassy smooth surface of welding iron, but when struck very gently with a hammer, it cracks in many places, and by a harder blow is shivered to pieces. When brought to a high heat and quenched suddenly in cold water, it becomes harder than at first, though not equally so with the finest cast steel in similar circumstances; but on the other hand, it is not capable of being sensibly softened by annealing as the other varieties of steel are. At a high heat it is fusible, and after being melted exhibits a close compact grain, is considerably brittle, and bears a very near resemblance to cast steel. From its analysis and other circumstances, it is considered by Dr. Pearson as differing from steel, only in containing a little oxyd of iron.

Comparison and analysis, of Cast Iron, Bar Iron, and Steel.

Notwithstanding the close attention of various eminent chemists to this important subject, much yet remains to be done before an entirely satisfactory theory can be formed to account for the different properties possessed by the various kinds of iron and steel. We shall endeavour to show in the present section, the progress that has already been made in this interesting analysis, and shall then point out some of the chief difficulties that yet remain to be overcome.

In all the varieties of iron and steel, the principal ingredient is metallic iron, and as this metal in the reguline state alone, has the property of giving out hydrogen gas while dissolving in dilute sulphuric or muriatic acids, the amount of inflammable gas thus produced has been adopted by Bergman, by Berthollet, and Pearson, as upon the whole the most satisfactory and compendious exponent of the quantity of reguline iron contained in any of the known varieties and forms of this metal. Thus a mixture of equal parts of reguline and oxydized iron by treatment with dilute sulphuric acid, will produce only half the quantity of hydrogen gas that an equal weight of pure iron would. But this can be admitted to be a perfectly accurate mode of proceeding, only where the mixture thus analyzed, contains nothing that is soluble in hydrogen gas at the temperature, and in the other circumstances under which the experiment is performed. None of the kinds of manufactured iron is entirely free from carbon, and this according to Berthollet is taken up by the nascent hydrogen as the metal dissolves in the acid, whence originates a material source of error, the quantity of gas produced depending not merely on the proportion of iron, but also of carbon in the mixture. It appears from Berthollet's experiments that when cast iron or steel is treated by dilute sulphuric acid, at a boiling temperature, in proportion as the metal dissolves, a black spungy matter is observed floating in the solution: the quantity of this increases till the process is about half over, then it begins to diminish, and will be found to have entirely disappeared by the time that the last portions of iron have dissolved. This black matter is carbon, which being insoluble in sulphuric acid or sulphat of iron, must necessarily have been taken up by the hydrogen. This accordingly is found to be the case, for the gas produced requires a greater proportion of oxygen for its combustion, and the result of

the process is a quantity of carbonic acid. This is further confirmed by an observation of Rinman's that the inflammable gas arising from the solution of steel, affords by combustion more fixed air than that which is produced from the solution of bar iron. From the numerous experiments of Berthollet on this subject, we have selected the six following as sufficient for our purpose, and having converted the weights and measures into English, it appears that at 29.84 Bar. and 59° Fahr.

Grs.	measures of inflammable gas.
100 of grey cast iron yield with diluted sulphuric acid	104.8 oz.
100 of bar iron made from the preceding - -	111.5 do.
100 of Steel from the preceding - -	108.3 do.
100 of Swedish bar iron - - -	114. do.
100 of Steel from the preceding - -	106.7 do.
100 of white cast iron from Eisenerz - -	97.4 do.

It might at first be supposed that a given quantity of hydrogen would increase in bulk in proportion to the carbon taken up by it, the reverse of this however is in fact the case: therefore if Swedish bar iron be considered as the pure state of this metal, represented by the number 114, the proportion of iron contained in an equal weight of steel made from the same will be more than 106.7, because the former number indicates pure hydrogen, but the latter carburetted hydrogen.

Dr. Pearson on the other hand, in his experiments on Wootz, assures us that when dilute sulphuric acid is acting on steel at the common temperature, a quantity of black carbonaceous matter is separated, which continues to augment so as to impede the effect of the acid; if at this period a lamp is applied, the increased temperature brings on a more rapid action, and the black sediment appears rather to diminish in quantity. This diminution however Dr. P. attributes only to the solution of the iron with which the carbon was combined, and not to the solution

of the carbon itself in the hydrogen: for, says he, the gas when burnt with oxygen procured from manganese, inflamed like common hydrogen, and whether procured by means of iron, or steel, or wootz, produced only a very slight turbidness with lime-water; whereas carburetted hydrogen, prepared by passing steam through hot charcoal, being treated in the same manner, rendered the lime-water quite milky. The proportions of gas from iron and steel were also remarkably less than those mentioned by Berthollet. 100 grains of wootz, by several experiments, yielded from 78 to 84 ounce measures of gas. 100 grains of steel wire, also by various experiments, yielded from 83 to 86 ounce measures of gas. 100 grains of iron wire yielded from 86 to 88 ounce measures.

How much soever the experiments of Berthollet and Dr. Pearson differ in other respects, yet we may infer that Swedish bar iron contains a larger proportion of reguline iron than the other varieties of bar iron, that steel contains a smaller proportion than bar iron, that wootz contains a still smaller proportion, that grey cast iron is inferior in this respect to steel, and that white cast iron is the least pure of any.

We also learn that the lower the temperature is at which the solution of the iron is made, the purer is the hydrogen that is produced, and with proper care that the objections raised by Berthollet to the accuracy of this mode of proceeding, may be completely done away. (? T. C.)

We have already mentioned that almost all the known varieties of iron and steel contain a larger or smaller proportion of carbon. The quantity of this in any particular sample of metal may best be ascertained by digesting the metal in dilute nitro-muriatic acid, which will leave untouched the carbon united with a little iron. This black insoluble residue being washed in warm water and

finally digested for a minute in weak ammonia, should be heated in a flask almost to redness, to expel the water and any muriat of ammonia that it may contain; being then weighed, it is to be ignited in a silver or platina crucible till the whole of the carbon is burnt off, and the residual iron is oxydized: from the weight of this oxyd is to be deducted 48 per cent. on account of the oxygen, and the difference between the weight of the remainder and that of the black powder before ignition indicates the amount of carbon.

The affinity of iron for carbon is pretty considerable, though it is by no means capable of decomposing carbonic acid by combining with its base, as Mushet has clearly shown in opposition to the assertion of Clouet.

The effects produced upon iron by carbon are very remarkable. First with regard to colour: the blueish grey tint of iron becomes more and more white in proportion as it combines with carbon, till it possesses almost a silvery colour and lustre, as is the case with the white cast iron in which state the metal seems to be saturated with carbon. At the same time that these changes of colour are going on, the tendency to crystallization is rapidly increasing, hence the fracture from being fibrous and hackly, becomes first compact, then granular, and at length exhibits facets like antimony. With these changes the fusibility increases, and the faculty of welding diminishes, and soon entirely ceases: the ductility and malleability also undergo an analogous change, though not quite to so great an extent: the hardness increases, as also does the property of induration by sudden cooling, and the capability of being tempered.

Iron however may not only be saturated but supersaturated with carbon: that is to say, when at a very high temperature it will dissolve more carbon than it can hold in solution at a lower temperature; and in consequence,

by slow cooling while it is still fluid, a part of this excess of carbon will separate from the rest of the mass and rise to the surface, forming a flasky crust of plumbago or carburet of iron. Some however of the plumbago will still remain enveloped by and dispersed through the iron, giving it an uniform dark grey or black colour if the proportion is considerable, or only mottling it if the excess of this substance is very slight.

The actual proportions of carbon contained in the different kinds of iron have not yet been ascertained with any accuracy either by analysis or synthesis; but thus much appears certain, that bar iron in general contains a smaller quantity than the softer varieties of steel, and these again always contain less carbon than the common and finer cast steel; that in the white, the mottled, the grey, and the black varieties of cast iron, the dose of carbon is constantly augmenting, in the last of which the proportion of carbon is probably about $\frac{1}{20}$ of the whole.

Oxygen is also contained in most of the varieties of iron, and the effects occasioned by it in the different processes to which this metal is subjected, require more attention than has hitherto been paid to them. Cast iron appears to be highly charged with oxygen, and on this account requires to be supersaturated with carbon in order to be converted with any economy into bar iron. It may seem at first a paradox to maintain the co-existence of oxygen and carbon in the same metallic mass, especially considering the great heat to which it is exposed in the process of reduction, since it is an universal and uncontroverted fact, that metallic oxyds are decomposed by carbon at a high temperature, the oxygen and carbon uniting together and being dissipated in the form of gas, the metallic regulus remaining behind. But when the roughness of the smelting process in blast furnaces, and the large quantity of materials operated on at once, as well as the great

pressure of the superincumbent scoriæ are taken into consideration, we shall cease to be surprised at the apparent anomaly. The existence of oxygen in cast iron, is manifest from the phenomena that accompany the operation of *puddling* as already described in a preceding section. The crude iron being subjected to a high temperature, under a pressure no greater than that of the atmosphere, the oxygen and carbon that it contains react upon each other and produce carbonic acid and gaseous oxyd of carbon, which having escaped, the metal is found reduced to a state of malleability. The same effects take place in close vessels, as Dr. Beddoes has well shown. If crude cast iron is put into a retort, as soon as the vessel and its contents have acquired a low red heat, an inflammable gas, mixed with carbonic acid, is given out with considerable rapidity (this inflammable gas must, from the circumstances, be the oxyd of carbon) when the production of gas ceases, the iron upon examination will be found to have lost somewhat of its weight, and to be nearly in the state of bar iron. But though this combination of the oxygen and carbon of the crude metal, and the consequent generation of air takes place with great ease when the beak of the retort is but just dipped under water, yet if the pressure amounts to five inches of water, in addition to the atmosphere, the disengagement of air proceeds very slowly, and entirely ceases if instead of the water, a single half inch of mercury is employed; although upon removing this obstacle the bubbles of air pass through as before.

By the treatment that cast iron undergoes during its conversion into malleable bar iron, the greater part of the oxygen and carbon is got rid of; still, however, a small quantity of oxygen, the smaller in proportion to the goodness of the iron, remains. This is inferred with much probability from the blistered appearance that the bars of

iron exhibit after having been converted into steel by cementation. These blisters are manifestly occasioned by the exudation of a gas from the bar, and this gas in all probability is oxyd of carbon. A further proof of the existence both of oxygen and carbon, even in Swedish bar, may be deduced from some interesting experiments by Mr. Mushet. Having put some pieces of Swedish bar iron into an earthen crucible, with a flux composed of marble and calcined clay, he observed first, that the earths melted together before the iron showed signs of fusion, and that while this latter was melting, bubbles of air were continually rising from it and passing through the vitrified flux: this gas burnt with a lambent blue flame, and probably was gasseous oxyd of carbon: the iron sustained a notable loss of weight, and had become considerably softer than at first.

Steel probably is entirely free from oxygen.

The action of vitrescent earthy mixtures comes next to be considered. It is certain that cast iron contains a very considerable proportion of scoriæ diffused through its substance, which are partly got rid of by subsequent fusion, as they rise to the surface of the metal, being considerably lighter than it, while such portions as still remain are got rid of, for the most part, by hammering and laminating during the conversion of the cast iron into bar. A very small proportion of scoriæ, however, is not unfrequently left in the iron, as is obvious from the earthy residue that some of the varieties of this metal leave behind them when dissolved in acids. It is not yet clearly made out what is the precise effect of a little earth on the malleability of iron. Clouet has endeavoured to show that it renders the iron softer and more malleable, but inclined to be hot short, and the experiment by which he demonstrates it, is the fusing together of iron and glass, by which the effects just mentioned are produced upon the metal.

But this is precisely the same experiment as that of Mr. Mushet's, related in the preceding paragraph, and M. Clouet having entirely overlooked the extrication of gas from the metal, has gratuitously attributed the change produced to a combination of the iron with a little of the glass, without, as appears, taking the trouble to substantiate his hypothesis by actual analysis.

Cast iron made with coke instead of charcoal, must necessarily contain a variable proportion of sulphur: nor is this substance very likely to be entirely dissipated by the subsequent refining that the metal goes through; and it appears from a direct experiment by Dr. Beddoes, that iron after being puddled and stamped, if treated with muriatic or sulphuric acid, will give out sulphuretted hydrogen. Bergman has shewn that certain varieties of iron contain manganese, and others phosphoric acid. Clouet has detected arsenic in some; and other chemists have somewhat obscurely intimated the presence of lead, copper, and zinc, which is far from improbable, as several of the ores of iron are occasionally mixed with galena, copper pyrites and blende. But the effect of these substances in small quantity on iron has not yet been ascertained by any experiments that can be depended on; it is therefore obvious how much remains to be done before we acquire a thorough knowledge, even on practical points, of this most important of all metals.

The following, in the present state of our researches on this subject, may be laid down as the essential characters of the principal forms under which iron exhibits itself. Crude cast iron, besides casual impurities contains carbon, oxyd of iron, and vitrified earth. The difference between white, mottled, grey and black cast iron depends on the proportion of carbon, which is smallest in the white and greatest in the black. By the process of refining or re-smelting, most of the earth and oxyd of iron rises to the

surface of the metal in the form of a dense slag; hence the residual iron differs from the crude pig-metal in containing less earth and oxyd. By the subsequent operations the carburet and oxyd of iron mutually decompose each other, forming carbonic acid and carbonous oxyd, by which the metal is freed both from its oxygen and carbon. In this state it forms bar iron, which may or may not retain a small proportion of vitrified earth, but which seems even when purest to hold a little both of carbon and oxyd. If this bar iron is exposed in a close vessel to a high heat, the carbon and oxygen that it contains (if they are in due proportion to each other) will be entirely got rid of, the metal will become very soft, and will be at the same time malleable and fusible. If the bar iron instead of being heated by itself has access to carbon either in the state of charcoal or plumbago, its oxygen will be expelled and carbon will at the same time be absorbed: if the portion of this latter be small, the mixture will partake of the properties both of iron and steel, hence it will be very malleable and capable of being welded, but also will be harder than pure iron, somewhat more fusible and susceptible of being tempered. By being united with a fresh portion of carbon it will become still more fusible and will lose its welding property; it will become harder, more compact, and will form the fine cast steel. A further portion of carbon increases the brittleness and hardness, so as to render it incapable of being wrought, and its colour and texture will approach to that of white cast iron: in this state it may be regarded as saturated with carbon. It is however capable of uniting to this substance even to supersaturation, by which its colour and texture resembles that of grey or black cast iron; its fusibility is somewhat increased but its hardness is so much lowered by this excess of carbon as to allow it to be wrought with ease by a common file, nor can it be materially hardened by sudden

cooling or be tempered, so that it is no longer in the state of steel. By a still further cementation with charcoal it would in all probability be converted into plumbago.

Many chemists have supposed that supercarbonized steel is the same thing as crude iron, because they resemble each other in their fracture and colour and contain carbon; and upon this reasoning have been founded several imperfect and ineffectual methods of applying the finer kinds of cast iron to some of the uses of common cast steel; but we have shewn that however great may be the resemblance in some points, yet cast iron essentially differs from steel in containing both earth and oxyd of iron, and therefore cannot be substituted for it with any success.

It only remains to say a few words concerning two states of bar iron called *hot-short* and *cold-short*.

Iron that is hot-short or red-short is very soft and ductile when cold, on which account it is generally employed in the manufacture of wire; it may also be hammered and welded if treated skilfully at a full white heat, but when it has cooled down to a cherry red, it breaks away before the hammer and is dissipated almost like sand.

Cold-short iron on the contrary is harder not only than hot-short but also than pure Swedish bar iron; it may be wrought in the usual way when red or white hot, but possesses no toughness when cold; so that a large bar may with ease be broken across by a common hand hammer.

Hot-short iron is imagined, rather than proved, to contain arsenic, to which its brittleness at a red heat is supposed to be owing.

Cold-short iron is supposed by Bergman to derive its characteristic qualities from a portion of phosphoric acid; and it is certain that phosphat of iron has been found in

iron of this description, both by the illustrious Swedish chemist just named and Meyer and Clouet.

If however it be granted that hot-short and cold-short iron respectively contain arsenic and phosphoric acid, yet it must in return be allowed that these qualities appear in very many cases where there is no reason to suspect either the one or the other, and that the methods by which these defects may be produced or remedied are in many cases at least not very reconcilable with their supposed origin.

If white cast iron, that is, such as is deficient in carbon, be exposed to the action of a current of flame after it has exhibited its proper degree of malleability, it will pass into the state of cold-short iron, and its brittleness will increase in proportion to the length of time that it is thus exposed. Does it not therefore seem probable that in many cases at least the defects of cold-short iron are occasioned by an absorption of oxygen? This however the advocates for the universality of Bergman's theory on this subject may allow with perfect consistency. They would say that the phosphat of iron originally contained in the ore is converted by the process of smelting into phosphuret of iron, which being capable of uniting perfectly with bar iron and forming only a very small proportion of the whole may render the iron hard without materially impairing its toughness while cold: but when this iron deprived of carbon is exposed at a high temperature to the action of the air, the phosphorus becomes acidified, and the phosphat of iron that hence results being incapable of combining with malleable iron is merely dispersed through it, and must therefore tend to render it brittle. Nor is the explanation of the fact contradicted by the methods made use of to correct this quality. Rinman says that cast iron which by the common treatment would yield cold-short bar, may be made to afford soft malleable iron by fusing

it with a mixture of equal parts of lime and scoriæ. Mr. Mushet says that 875 grains of cold short iron when melted by itself in a covered crucible formed a perfect button covered by a thin film of brown glass. The metal weighed only 805 grains, and instead of being cold-short, was now found to have acquired the opposite fault of being hot-short, it was extremely soft and ductile. In these experiments it may be said that the metal being brought to a state of quiet fusion, the phosphat of iron either entirely or at least for the most part separated in the form of glass from the reguline portion. But as all the above phenomena may be accounted for equally well upon the supposition that the cold-short quality is owing simply to the mixture of oxyd of iron with the metal, it would be useless to speculate further on the subject till a sufficient number of accurate analyses have been performed to direct our investigations. The hot-short quality appears to be occasioned by the admixture of some substance which enters into fusion at a low red heat, and thus destroys the tenacity of the iron through which it is diffused: hence this variety of iron cannot bear the hammer at a red heat, though when the temperature is raised to the full welding point, the effect of this unknown substance is counteracted by the tenacity which the particles of iron then acquire. This substance has been by some supposed to be carbon, but this is inconsistent with the extreme softness which always characterises hot-short iron: for the same reason it cannot be phosphorus. The effects are more like those of a metallic body; and lead, arsenic, copper, and zinc may be each suspected with almost equal probability. In some varieties of hot-short iron, especially those made with coke, the fragility increases with the increase of temperature, and they are wholly incapable of welding: this probably arises from a large admixture of the same substance, whatever it be, to which

the more usual characters of hot-short iron are owing, with perhaps a little sulphur.

Physical properties of Iron and Steel.

Iron whether in the states of cast or bar iron, or steel, is attractable by the magnet, and capable of acquiring polarity, this last property however is more durable and powerful in steel than in any of the other forms of this metal.

Supercarbonized cast iron is of a dark grey almost black colour, has a granular fracture, is very brittle, is more fusible than the other kinds of cast iron, and yields without difficulty to the file. White cast iron is of a tin-white colour, and a coarse grained fracture; it is brittle but very hard, and less fusible than the preceding variety. The grey and the mottled varieties approach nearer to the one or the other in proportion to their colour. The specific gravity of cast iron has not been ascertained with great exactness, and no doubt is subject to some variations: that which is most highly carbonized has the least specific gravity, nor does it probably ever much exceed 7.01. Cast iron takes impressions from moulds with much more sharpness and precision than any other metal: and when in fusion if pieces of cast iron are thrown in, they will be observed to float on the surface till they melt and mix indistinguishably with the rest; hence it has been generally acquiesced in that melted cast iron is of greater specific gravity than when solid; contrary to what takes place in all the other metals. This however seems to be founded on a mere fallacy, for if it were true, the iron when poured into a mould and beginning to solidify, ought to spirt out part of the melted metal, as water does under similar circumstances when converting into ice: whereas on the contrary, a considerable contraction happens which obliges the workmen who are employed in casting large pieces, to fill the runners or channels into the mould with melted metal, lest any cavities should be

formed in the piece and thus spoil it. Further, this contraction is so well known, that when castings of particular dimensions are required, the mould is constantly made larger than the pattern by $\frac{1}{96}$ or sometimes $\frac{1}{64}$, to allow for the shrinking. Now it is impossible that this should happen if the specific gravity of the melted metal really exceeded that of the solid metal: how then does it happen that the solid will float on the fluid metal? the answer to this is not perhaps very obvious; but it may be remarked that not only solid cast iron but even bar iron which is of considerably greater specific gravity, and not only bar iron but even lead which is more than half as heavy again as cast iron, will float upon its surface. But though cast iron like all other metals shrinks when it becomes solid, yet at the instant of congealing it appears to undergo a momentary expansion, and thus takes a remarkably perfect impression of any pattern with which it comes in contact.

Bar iron is of a bluish white colour, has a fibrous hackly fracture, is malleable both when hot and cold, and is capable of uniting with another piece of bar iron by welding: it may be drawn into very fine wire and is the most tenacious of all metals, a wire $\frac{1}{10}$ of an inch in diameter being capable of sustaining from 450 to 500lbs. before it breaks. It is fusible, but requires for this purpose a higher heat than cast iron. Its specific gravity is subject to some variations: that of common hammered iron, according to Dr. Pearson, is from 7.45 to 7.6: Swedish bar iron varies between 7.70 and 7.78. It expands like all other metals by heat: the amount of its expansion for every degree of Fahrenheit's thermometer between the freezing and boiling point of water, is equal to 0.000006358.

Steel is of a light-grey colour and a fracture more or less fine granular: it is harder and more brittle than bar iron in proportion to the quantity of carbon that it con-

tains; when slightly charged with this substance it is malleable, ductile, weldable and elastic, but when more nearly saturated with carbon it is not capable of being welded, and its fusibility is increased. It may be hardened by sudden cooling, and may afterwards be made softer by tempering. Its specific gravity varies much: that of the best blistered steel before hammering is =7.31, of the same after hammering =7.73: of very hard steel =7.26: of melted steel wire =7.5: of English cast steel hammered, from 7.82 to 7.91.

Report concerning the Art of making fine Cutlery—From 4 Nicholson's Journal, quarto, page 127.

The fabrication of edge tools is one of the first arts among men in every state of society. Artizans are well aware of the necessity, that the instruments of their respective trades should be made to possess the qualities adapted to the operations by which they gain their subsistence; and among the various sub-divisions of labour, there is perhaps no material, upon which the skill and judgment of practical men are more multifariously exercised than steel. The makers of files, of chissels, of planes, saws, and the infinite variety of knives, all occupy their several departments separate from each other, and possess their respective degrees of celebrity among workmen, which are grounded on their knowledge of the peculiar kinds of steel, as well as the methods of working them, which are best suited to the intended operations. Many of these methods are kept secret; but in general the philosophical enquirer will find the communications of operative men, to the full, as liberal and open as the circumstances of the case may seem to warrant. Many manufacturers have no reserve with regard to the manipulations of their art, and have the spirit to assert their claims to public encouragement, upon the open ground

of the address and integrity with which they conduct their professional labours.

Among the instances of this kind which have occurred to me during a life of diligent enquiry, I have lately been much gratified by the ready assistance and communications of Mr. Stodart of the Strand, which enable me at present to communicate my own notions on the subject of fine cutlery, with the advantage and support of his successful experience; which I shall proceed to do without further preface.

It appears to be at present generally agreed, that for all works which do not require welding, cast steel is preferable to any other. For fine cutlery it undoubtedly is. Mr. Stodart uses those bars which are marked Huntsman, but does not suppose it to be of a better quality than that of Walker, and other manufacturers. He complains, that it is much worse in quality now than formerly, which complaint I have also heard from other intelligent artists. I did not ask him concerning the art of forging, but take it for granted, that it consists in little more than the acquired skill of managing the bar and the hammer, with the precautions not to injure the texture by strong hammering at too low a heat, or to degrade the quality of the steel, by too much heat or exposure to the current of air from the bellows.

Cutlers do not use any coating to their work at the hardening heat, as the file cutters do; and indeed it seems evidently unnecessary when the article is intended to be tempered and ground. Mr. S. agrees with me, that the best rule is to harden as little as possible above the state intended to be produced by tempering. Work which has been overheated has a crumbly edge, and will not afford the wire hereafter to be described. The proper heat is a cherry red visible by day-light. He has not found that any advantage is obtained from the use of salt in the water,

or cooling that fluid, or from using mercury instead of water; but it may be remarked, that questions respecting the fluid, are, properly speaking, applicable only to files, gravers, and such tools as are intended to be left at the extreme of hardness. Yet though Mr. Stodart did not seem to attach much value to peculiarities in the process of hardening, he mentioned it as the observation and practice of one of his workmen, that the charcoal fire should be made up with shavings of leather: and upon being asked, what good he supposed the leather could do, this workman replied, that he could take upon him to say, that he never had had a razor crack in the hardening since he had used this method, though it was a very common accident before.

One of the greatest difficulties in hardening steel works of any considerable extent, more especially such articles as are formed of thin plates, or have a variety of parts of different sizes, consists in the apparent impracticability of heating the thicker parts, before the slighter are burned away; besides which, even for a piece of uniform figure, it is no easy matter to make up a fire which shall give a speedy heat, and be nearly of the same intensity throughout. This difficulty formed a very considerable impediment to my success in a course of delicate steel work, in which I was engaged about seven years ago; but after various unsuccessful experiments, I succeeded in removing it by the use of a bath of melted lead, which for very justifiable reasons has been kept a secret till now. Pure lead, that is to say, lead containing little or no tin, is ignited to a moderate redness, and then well stirred. Into this the piece is plunged for a few seconds; that is to say, until when brought near the surface that part does not appear less luminous than the rest. The piece is then speedily stirred about in the bath, suddenly drawn out and plunged into a large mass of water. In this man-

ner a plate of steel may be hardened so as to be perfectly brittle, and yet continue so sound as to ring like a bell; an effect which I never could produce in any other way. Mr. Stodart has lately made trial of this method, and considers it to be a great acquisition to the art, as in fact I found it.

The letting down, or tempering of hard steel, is considered as absolutely necessary for the production of a fine and durable edge. It has been usual to do this by heating the hardened steel, till its bright surface exhibits some known colour by oxidation. The first colour is a very faint straw colour, becoming deeper and deeper by increase of heat, to a fine deep golden yellow, which changes irregularly to purple, then to an uniform blue, succeeded by white and several successive faint repetitions of these series. It is well known, that the hardest state of tempered instruments, such as razors and surgeons instruments, is indicated by this straw colour; that a deeper colour is required for leather cutter's knives, and other tools that require the edge to be turned on one side; that the blue which indicates a good temper for springs, is almost too soft for any cutting instrument except saws, and such tools as are sharpened with a file; and that the lower states of hardness are not at all adapted to this use. But it is of considerable importance, that the letting down or tempering, as well as the hardening, should be effected by heat equally applied, and that the temperatures, especially at the lower heats, where greater hardness is to be left, should be more precisely ascertained than can be done by the different shades of oxidation. Mr. Hartley first practised the method of immersing hard steel in heated oil, or the fusible compound of lead five parts, tin three, and bismuth eight. The temperature of either of these fluids may be ascertained in the usual manner, when it does not

exceed the point at which mercury boils: and by this contrivance the same advantages are obtained in lowering the temperature of an whole instrument, or any number of them at once, as have already been stated in favour of my method of hardening. Oil is preferable to the fusible mixture for several reasons. It is cheaper; it admits of the work being seen during the immersion by reason of its transparency; and there is no occasion for any contrivance to prevent the work from floating.

I requested Mr. Stodart to favour me with an account of the temperatures at which the several colours make their appearance upon hardened steel; in compliance with which, he made a series of experiments upon surgeons needles hardened, highly polished, and exposed to a gradual heat while floating at the surface of the fusible mixture. The appearances are as follow:

No. 1. taken out at 430° of Fahrenheit. This temperature leaves the steel in the most excellent state for razors and scalpals. The tarnish, or faint yellowish tinge it produces, is too evanescent to be observed without comparison with another piece of polished steel. Instruments in this state retain their edge much longer than those upon which the actual straw colour has been brought, as is the common practice. Mr. S. informs me, that 430° is the lowest temperature for letting down, and that the lower degrees will not afford a firm edge.

No. 2 at 440°, and 3 at 450°. These needles differ so little in their appearance from No. 1, that it is not easy to arrange them with certainty when misplaced.

No. 4 has the evident tinge which workmen call pale straw colour. It was taken out at 460°, and has the usual temper of penknives, razors, and other fine edge tools. It is much softer than No. 1, as Mr. Stodart assures me, and this difference exhibits a valuable proof of the advantages of this method of tempering.

Nos. 5, 6, 7 and 8, exhibit successive deeper shades of colour, having been respectively taken out at the temperatures 470°, 480°, 490,° and 500°. The last is of a bright brownish metallic yellow, very slightly inclining to purple.

No. 9 obtained an uniform deep blue at the temperature of 580°. The intermediate shades produced on steel by heats between 500° and 580° are yellow, brown, red, and purple, which are exhibited irregularly on different parts of the surface. As I had before seen this irregularity, particularly on the surface of a razor of Wootz, and had found in my own experience, that the colours on different kinds of steel do not correspond with like degrees of temper, and probably of temperature in their production, I was desirous that some experiments might be made upon it by the same skilful artist. Four beautifully polished blades were therefore exposed to heat on the fusible metal. The first was taken up when it had acquired the fine yellow, or uniform deep straw colour. The second remained on the mixture till the part nearest the stem had become purpleish, at which period a number of small round spots of a purpleish colour appeared in the clear yellow of the blade. The third was left till the thicker parts of the blade were of a deep ruddy purple, but the concave face still continued yellow. This also acquired spots like the other, and a slight cloudiness. These three blades were of cast steel; the fourth, which was made out of a piece called Styrian steel, was left upon the mixture till the red tinge had pervaded almost the whole of its concave face. Two or three spots appeared upon this blade, but the greater part of its surface was variegated with blue clouds, disposed in such a manner as to produce those waving lines which in Damascus steel are called the water. Two results are more immediately suggested by these facts; first, that the irregular production of deep colour

upon the surface of brightened steel, may serve to indicate the want of uniformity in its composition, as well as the method by an acid which has before been explained in this work; and second, that the deep colour being observed to come on first at the thickest parts, Mr. Stodart was disposed to think, that its more speedy appearance was owing to those parts not having been hardened. But upon trial with a plate of steel made quite hard at one end, and left soft at the other, I found that heat applied in the middle produced the regular changes at both ends precisely in the same manner. I suppose, therefore, that the thicker parts sinking deeper into the hot metal, experienced a stronger re-action and better contact, which may have accelerated the communication of heat. It may be here noticed, that we found upon repeating the experiment of applying nitrous acid to bright steel, which was hardened in part only, the black tinge appeared more speedily and strongly upon the hard parts, than the rest of the surface: a remarkable event, for the explanation of which I have no theory to offer.

Let us now suppose our cutting instrument to be forged, hardened, and let down or tempered. It remains to be ground, polished, and set. The grinding of fine cutlery is performed upon a grindstone of a fine close grit, called a Bilson grindstone, and sold at the tool shops in London at a moderate price. The cutlers use water, and do not seem to know any thing of the method by tallow. The face of the work is rendered finer by subsequent grinding upon mahogany cylinders, with emery of different fineness, or upon cylinders faced with hard pewter, called laps, which are preferable to those with a wooden face. The last polish is given upon a cylinder faced with buff leather, to which crocus, or the red oxide of iron is applied with water. This last operation is attended with considerable danger of heating the work, and almost instant-

ly reducing its temper along the thin edge, which at the same time acquires the colours of oxidation.

The setting now remains to be performed, which is a work of much delicacy and skill: so much so indeed, that Mr. Stodart assures me, he cannot produce the most exquisite and perfect edge if interrupted by conversation, or even by noises in the street. The tool is first whetted upon a hone with oil, by rubbing it backwards and forwards. In all the processes of grinding or wearing down the edge, but more especially in the setting, the artist appears to prefer that stroke which leads the edge according to the action of cutting, instead of making the back run first along the stone. This proceeding is very judicious; for if there be any lump or particle of stone, or other substance lying upon the face of the grinder, and the back of the tool be first run over it, it will proceed beneath the edge, and lift it up, at the same time producing a notch. But on the other hand, if the edge be made to move foremost, and meet such a particle, it will slide beneath it and suffer no injury. Another condition in whetting is, that the hand should not bear heavy: because it is evident, that the same stone must produce a more uniform edge if the steel be worn away by many, than by few strokes. It is also of essential importance, that the hone itself should be of a fine texture, or that its siliceous particles should be very minute. Mr. Stodart informs me that there are no certain criterions by which an excellent hone can be distinguished from one of ordinary value, excepting those derived from the actual use of both: that the Turkey stone cuts fast, but is never found with a very fine grit: that the yellow hone is most generally useful, and that any stone of this kind requires to be soaked in oil, and kept wet with that fluid, or otherwise its effects will be the same as that of a coarser stone under the better treatment: and lastly, that there is a green hone found in

the old pavement of the streets of London, which is the best material yet known for finishing a fine edge.

The grindstone leaves a ragged edge, which it is the first effect of whetting to reduce so thin, that it may be bended backwards and forwards. This flexible part is called the wire, and if the whetting were to be continued too long, it would break off in pieces without regularity, leaving a finer, though still very imperfect edge, and tending to produce accidents while lying on the face of the stone. The wire is taken off by raising the face of the knife to an angle of abut 50 degrees with the surface of the stone, and giving a light stroke edge foremost alternately towards each end of the stone. These strokes produce an edge, the faces of which are inclined to each other in an angle of about 100 degrees, and to which the wire is so slightly adherent, that it may often be taken away entire, and is easily removed, by lightly drawing the edge along the finger nail. The edge thus cleared is generally very even: but it is too thick, and must again be reduced by whetting. A finer wire is by this means produced, which will require to be again taken off, if for want of judgment, or delicacy of hand, the artist should have carried it too far. But we will suppose the obtuse edge to be very even, and the second wire to be scarcely perceptible. In this case the last edge will be very acute, but neither so even nor so strong as to be durably useful.

The finish is given by two or more alternate light strokes with the edge slanting foremost, and the blade of the knife raised, so that its plane forms an angle of about 28 degrees with the face of the stone. This is the angle which by careful observation and measurement, I find Mr. Stodart habitually uses for the finest surgeons instruments, and which he considers as the best for razors, and other keen cutting tools. The angle of edge is therefore about 56 degrees.

The excellence and uniformity of a fine edge may be ascertained, by its mode of operation when lightly drawn along the surface of the skin, or leather, or any organized soft substance. Lancets are tried by suffering the point to drop gently through a piece of thin soft leather. If the edge be exquisite, it will not only pass with facility, but there will not be the least noise produced, any more than if it had dropped into water. This kind of edge cannot be produced, but by performing the last two or more strokes on the green hone.

The operation of strapping is similar to that of grinding or whetting, and is performed by means of the angular particles of fine crocus, or other material bedded in the face of the strap. It requires less skill than the operation of setting, and is very apt, from the elasticity of the strap to enlarge the angle of the edge, or round it too much.

Letter on the Properties of tempered Steel.

To Mr. NICHOLSON.

SIR,

In one of your Journals, I do not recollect which, you signified your intention of giving in a future number, some ideas upon certain singular properties of tempered steel. A number of unexplained facts have for some time been known to the workers of steel-plate. As I am concerned in a manufactory of the kind, and in the daily habit of witnessing those curious and anomalous appearances, I thought you might in some measure profit by the following description of the changes which take place in the various processes of hardening, tempering, hammering, burnishing, &c.

I took a steel-plate 30 inches long, 12 broad, and about ,04 thick; I hardened it in a composition of oil and tallow, and afterwards tempered it down to a spring temper; it was now so elastic as to recover its position after being

bended; by hammering it to set it straight, it lost a part of its elasticity; after being ground in the same manner as a saw, the elasticity, became still less, having nearly returned to the same state as before hardened; it was then very uniformly heated till it became blue, it now recovered the whole of its elasticity; after being glazed bright upon a glazier coated with emery, the elasticity was found to be impaired, but in a less degree than when it was ground; the same effect was also produced by rubbing with emery or sand-paper, and also by burnishing; invariably the elasticity was recovered by bluing, and hence this is always the last operation in the manufactory of elastic steel-plate. Should you at some future opportunity favour the public with your opinion on this subject, and these hints have in the least assisted your inquiry, it will be the utmost wish of

Your humble and obedient servant,

Sheffield, T. B.
June 18, 1806.

On the Choice of Steel, and the Methods of hardening and tempering it.

For ordinary purposes, the method noticed by Mr. Collier in his paper on iron and steel, will answer very well, both for hardening and tempering; but in many cases it is necessary that the steel should be of the best quality, and be both hardened and tempered in such a manner as to preserve the greatest hardness possible without brittleness; and steel is of more or less value in proportion as it possesses this property in a greater or less degree.

Steel, when soft, can be wrought into almost any form as well as iron, welding excepted, of which the better sorts, particularly cast steel, are incapable. It can be forged, filed, turned in a lathe, drawn into wire, rolled into large plates, &c. &c. and, when by these means brought into

the desired form, it can then be made so hard as to be capable of cutting the hardest substances (the precious stones excepted), while at the same time it is almost proof against being itself worn by friction: but in this state it is brittle, like all other hard substances, and for many purposes must have this brittleness lessened, and this is what is termed by workmen, tempering, and consists in giving it certain degrees of heat according to the temper desired, which may be produced in any degree until the whole effect of hardening is destroyed, and the steel is reduced to its soft state. On each of these operations I shall offer a few remarks, proved by long experience; and, first, on the choice of steel for such purposes as require the best that can be procured for making cutting instruments, such as gravers, punches, turning tools, chisels, &c. &c. to be employed in turning or cutting tempered steel, and substances that are too hard to be cut by tools made of ordinary steel: for these purposes cast steel is undoubtedly the best; but even this sort differs in quality.

The general mode of choosing such as is most suitable for the above purposes is to break a bar, and observe its fracture, and to select the closest grained; but this mode is not always certain, owing to the difference made in the fracture by the steel being hammered under a greater or less degree of heat, steel being much improved by being hammered under a low heat, and even when cold; and when overheated, being quite spoiled for the above purpose. It is owing to this circumstance that the best sorts of cast steel are incapable of being welded as above mentioned. Another method is, to harden with as low a heat as possible a piece of steel, and then to break it, and observe its fracture: but this is not wholly to be depended upon; for some steel breaks with a very close grain, and yet is not of a good quality. But the surest method is to

have one end of a bar drawn out into a small rod under a low heat, an obscure red for instance, or but little above; then heat it as before, and suddenly plunge it into pure cold water: if it proves hard, and requires a great force to break it, it is good, let its fracture be what it may: and I have always found that the specimens that hardened with the lowest heat, and when in that state required the greatest force to break them, proved the best steel. Having thus selected steel fit for the required use, and, with the precautions already noticed, given it the proper form, it may be hardened; but the same method will not answer for all purposes. Some pieces, from their size and figure, are very difficult to be hardened; if they are large, they heat the water in immediate contact with them, and the heat is communicated to the rest of the water, so fast that it prevents the pieces from being cooled quick enough to produce the desired effect: this is in part prevented by continually moving the piece about in the water; but when too large to be hardened by this method, a stream of water must be employed; and for such pieces as the face of large anvils, a birch broom is used with advantage to break the bubbles that are formed by the continual disengagement of air, and which, if not swept away, would prevent that intimate contact and uniform succession of the stream necessary to produce the degree of hardness required. Other articles from their length, are difficult, and almost impossible to be made hard without bending, or otherwise altering their figure: this circumstance occasions a great deal of trouble; and many a piece of work is spoiled, after a good deal of labour has been bestowed upon it. The method that has succeeded best with me is, either to inclose the piece or pieces intended to be hardened in an iron case or box, open at one end (for the more ready dropping the pieces into the water), and giving it a slow yet regular heat; then to take the case out

of the fire, and drop the pieces into the water in such manner as will allow them to come as little as possible in contact with the air. This method answers two good purposes at once, causing the heat to be more equally applied, and preventing the contact of the air, and of course any scaling; and when the work has been polished and well defended from the air, it comes out nearly as clean as it was before. When the greatest possible hardness is required, it may be obtained by using quicksilver instead of water; but this can only be employed for small articles. For some purposes steel is required to have a superior degree of hardness given to its surface, such as in the case of files, &c. This is obtained by using a coarse powder made of leather slightly burned, hair or horn, either in raspings or in powder; this is mixed with a little common salt, and the files when just red hot, are thrust into a heap of this powder, some of which adhering to their surface is carried into the fire with them, and gives them a case hardening: the salt fluxes upon their surface, and defends them from the air while passing from the fire into the trough of water, into which they are plunged to harden. The workmen say, the longer this water is used for this purpose the better.

We are now come to the last process called tempering, for one method of which see Mr. Collier's paper; but that method cannot be conveniently applied in all cases, and has several disadvantages, some of which I shall mention. First, each piece must be made bright that the change of colour may be better seen, and must be heated singly or nearly so; and pieces of irregular figure cannot be made to receive an equal degree of heat in all their parts, so that some will be softer than others. These circumstances would retard the manufactory of many articles very much, and prevent their being afforded at the present prices, such as the springs of gun locks, door

locks, various articles in clock and watch work, &c. &c. The necessity of making them bright enough to mark the change of colour is obviated by smearing them with oil or tallow, which helps to apply the heat more uniformly, and marks the temper as well as by observing the colour, or nearly so; or by putting the things to be tempered into a proper vessel, and adding so much oil or tallow as will cover them, and then holding them over the fire or the flame of a lamp until a sufficient heat is given. By this means the most irregular pieces may be uniformly heated, and great numbers may be done at one time, and with great certainty: thus are clock and watch pinions, watch verges, balances, &c. tempered; sometimes many dozens at once; and no more time is necessary for the whole than would be for one single article. The requisite temper may be known by the following circumstances: When such a heat is given that the tallow is first observed to smoke, it indicates the same temper as that called a straw colour: this will reduce the hardness but little; but if the heat is continued until the smoke becomes more abundant, and of a darker colour, it will be equal to a brown, and indicates a temper that may be wrought—that is, which may be turned or filed, but with difficulty, and only when a mild sort of steel is employed. If the tallow be heated so as to yield a black smoke, and still more abundant, this will denote a purple temper; and if the steel is good, it will now work more pleasantly, though still hard enough to wear well in machinery. The next degree may be known by the tallow taking fire if a lighted body is presented to it, but yet not so hot as to continue to burn when the light is withdrawn; this would equal a full blue colour. Increase the heat till the tallow continue to burn, being once lighted, and this will denote a pale blue: and if the whole of the tallow be allowed to burn away, or to burn dry, as the workmen call

it, it gives what clock-makers mostly use for their work. Farther tallow is useless; a small degree of heat more would just be seen in a dark place, or the lowest degree of a red heat: such is the temper given to the springs for coaches, &c. Thus I have given a reason why oil or tallow is made use of, and given you the parallel degrees of temper which by a dry heat are observed by the change of colour only. The method of hardening in quicksilver is of great use where a superior degree of hardness is required; and good steel so hardened, when the precautions before mentioned are duly attended to, will cut glass like a diamond, and turn or cut other steel at so high a temper as to differ but little from quite hard.—Perhaps at a future time I may give you a method by which this hardest of steel may also be worked with considerable ease, and the cases in which I have applied it to advantage.

As steel is always found more compact and strong bodied when hardened with a low heat, and as that effect is best obtained the colder the water is which is employed hardening it, provided the water is clean, (a circumstance which should always be attended to,)—it appeared probable, that if water was cooled down to the freezing point, or even lower, which it may be, and retain its fluidity by being kept in a state of perfect rest, the effect might be heightened. I caused a large heap of snow to be collected together at a time when the thermometer stood at 22° of Fahrenheit, and making a deep hollow in the middle, I set a glass of clean water in the bottom of the hollow, and covered the whole with a board to prevent the air from disturbing or causing any motion in the water. I heated some pieces of steel in the breech end of a gun barrel to a low red heat; and by means of an assistant to take off the board at the instant I arrived with the heated barrel and its contents, I quickly dropped the pieces into the water; which having stood all the preceding night in the

situation above described, must, though still fluid, have been cooled down to the temperature of the surrounding snow, which was still found to be 22°. Upon taking them out, I found the pieces hard but brittle, having the appearance of steel that had been overheated.

Being disappointed in what I had expected, I intended to repeat the experiment with a still lower heat; but an alteration in the state of the air prevented me from prosecuting the experiment at that time, and having since succeeded in making use of quicksilver instead of water; I have never resumed the experiment. As methods are now well known by which water may be cooled below the freezing point, even by the fire side, and at an easy expense, some one who has time may perhaps think the experiment worth repeating: it might cast some light upon the subject of hardening steel, and lead to some useful results

The dish I employ for tempering is made of plate-iron, with an edge turned up on every side a sufficient height to hold tallow or oil enough to cover the pieces to be tempered. The corners are nipped together, and then folded up against the sides; by which means they are prevented from letting out the oil.

Another turned up on three sides only, is used to lay pieces intended to be hardened: a cover is of advantage where the pieces are intended to come out clean and bright, as it more perfectly defends them from the air, and of course prevents oxidation from taking place. By this instrument, the work, though ever so small or slender, may be brought out of the fire and dropped into the water with very little loss of heat. It ought to be made of stronger plate-iron than is necessary for the other pan, and the corners cut out so that the sides may bend up more square. They need not be folded as in the other, not

being intended to hold any liquid substance. Such articles as small drills, pendulum and other small springs, need not be dropped into water, but only made to pass through the air by tossing them out and letting them fall to the ground, which will make them hard enough for most purposes.

Small drills may be hardened by holding their points in the flame of a candle, and, when sufficiently hot, suddenly plucking them out: the air will harden them; and they may then be tempered, by taking a little of the tallow upon their point, and then passing them through the flame at about half an inch above the point, and holding them there till the tallow begins to smoke. This method, known to all watchmakers, may be of use to other artists, and therefore not unworthy of the notice I have taken of it. S. Varley. 2 Phil. Mag.

Properties of blued Steel not generally known.

IN making springs of steel the metal is drawn or hammered out and fashioned to the desired figure. It is then hardened by ignition to a low red heat and plunging it in water, which renders it quite brittle. And lastly, it is tempered either by blazing or bluing. The operation of blazing, consists in smearing the article with oil or fat, and then heating it till thick vapours are emitted and burn off with a blaze. I suppose this temperature to be nearly the same as that of boiling mercury, which is generally reckoned to be at the 600 of Fahrenheit, though for reasons I shall in future mention, I think this point requires to be examined. The operation of bluing consists in first brightening the surface of the steel, and then exposing it to the regulated heat of a plate of metal or a charcoal fire, or the flame of a lamp until the surface acquires a blue colour by oxidation. The remarkable facts which I have here to present to the notice of philosophers, are, that Mr.

Stodart assures me that he has found the spring or elasticity of the steel to be greatly impaired by taking off the blue with sand paper or otherwise; and, what is still more striking, that it may be restored again by the bluing process without any previous hardening or other additional treatment.

Mr. Hardy, who is meritoriously known as a skilful artist, assured me some time ago that the saw-makers first harden their plates in the usual manner, in which state they are more or less contorted or warped, and are brittle;—that they then blaze them; which process deprives them of all springiness, so that they may be bended and hammered quite flat, which is a delicate part of the art of saw making;—and that they blue them on an hot iron which renders them stiff and springy without altering the flatness of their surface. Mr. H. finds that soft, unhardened steel, may be rendered more elastic by bluing, and that hard steel is more expansible by heat than soft.

It is very difficult to reason or even to conjecture upon these facts. They certainly deserve to be verified by a direct process of examination. 12 Nich. Jour. 63.

Observations and experiments on steel, resembling that of Damascus; with an easy test for determining the uniform quality of steel before it is employed in works of delicacy or expence.

In the infancy of society the hardest bodies, such as stones, and certain kinds of wood, were selected and used for cutting instruments, and still are applied to that purpose in several parts of the world. These materials were succeeded by copper, hardened by a mixture of tin, of which numerous weapons yet remain in the cabinets of the curious. And lastly, steel, whether obtained directly from the ore, or by cementation of malleable iron, has deservedly taken place of every other article, on ac-

count of the united qualities of tenacity and hardness. When the sword was the chief weapon of war, it must have been an object of great interest and demand to give to its blade a durable keen edge, and a degree of firmness or strength, which, without rendering it unwieldy, should ensure the warrior against exposure to the fatal accident of its breaking in the act of combat. The sabres of Damascus have been famous for ages, and still bear a great price in the East; but we have no decided account of the manner in which this steel is manufactured or made up. Some years ago I was favoured with the possession of a true blade of this kind for a few days, which, if my recollection be accurate, had cost the possessor twelve guineas at Constantinople. I know the sum was not less than this. As I was not permitted to make any experiments upon it, I could only ground my process upon reasoning from its external appearance and obvious qualities.

It had a dull grey or bluish appearance, was scarcely harder than common steel from the forge, was not easily bended, and when bended had no spring to recover its figure. Its back was smooth, as were also two narrow sloped surfaces which formed its edge under an angle of about 40 degrees; but its flat sides were every where covered with minute waving lines in masses in all directions, not crossing each other, and, for the most part, running in the direction of its length. The lines were in general as fine as harpsichord wire, not extremely well defined nor continued; and their distinction from each other was effected by no perceptible indentation of the surface, but rather by the succession of parts differing in the degree of polish or brightness. No one, upon inspection of this surface, would for a moment have imagined or allowed that it could have been done by engraving or etching, as the false blades are damasked. I was informed that if any part of this blade were made smooth by grinding or whet-

ting, the wavy appearance, called the water, could be again produced by means of lemon juice; and that its excellencies were, that it could be depended upon not to break, and that it would cut deeper into a soft substance, such as a pack of wool, or into flesh, than any other kind of blade.

From these circumstances, as well as from the price, I was induced to think that the blade was composed of steel and iron, and that the process of forging was such as greatly to enhance the cost, by the labour and management it might require. For if we suppose the pieces to be united together at the welding heat, and then forged or drawn out, it is certain that no small degree of skill and care would be required to render all the parts sound, and at the same time preserve the steel and iron in possession of their characteristic properties. Too great a heat would probably render the whole mass more uniform than is consistent with the subsequent production of the water or wavy appearance. In my attempt to imitate this steel, I endeavoured to substitute a mechanical contrivance in the place of this supposed careful forging.

I caused a cylindrical hole of about one inch in diameter to be bored through a piece of cast iron, the lower part of which could be so placed upon an anvil as to close one end of the hole. A forged iron plug was made nearly to fit the cylindrical hole, but considerably longer. Equal weights of German steel and Swedish iron, both in filings, were then well mixed with oil, and wrapped in a paper, which had before been rolled upon the plug, and consequently fitted the cylinder. The ends of the paper were neatly folded; and the whole mass being then put into the cast-iron cylinder placed upon the anvil, a few blows were given by driving the plug into the hole with a heavy hammer. By this means the mass of filings, when thrust out of the cylinder, was compact and manageable.

It was then placed in a charcoal fire, and urged to a welding heat by the double bellows. Thence it was taken with the tongs; again hastily put into the cylinder, and hammered by means of the plug and the heavy hammer. When it was taken out, the whole was found to be consolidated; but upon forging it into a plate, a considerable portion flew off in a crumbly form. The plate, however, was filed up, smoothed, and examined.

Its colour presented nothing remarkable. When weak nitrous acid was poured upon it, it became mottled in consequence of the numerous small black spots which appeared upon the particles of steel, while those of iron remained clean. On the nitrous acid being washed off, the surface appeared wavy like the Damascus steel, but scarcely at all fibrous; doubtless because the solid had not been drawn out by forging. An attempt was made to harden it by ignition and cooling in water; but it still remained soft enough to be cut with the graving tool, the point of which did not indicate any difference in that respect between the parts of iron and of steel, though it is very probable such a difference did really exist.

I infer, therefore, that the Damascus steel is in fact a mechanical mixture of steel and iron; that it is incapapable of any considerable degree of hardness, and consequently is in no danger of breaking from its brittleness; that its tenacity is ensured not only from the admixture of iron, but likewise from the facility with which its soundness may be ascertained throughout, by the same process which exhibits the water or fibrous appearance: and, lastly, that the edge of a weapon formed of this material must be rough, on account of the different resistance which the two substances afford to the grindstone, in consequence of which it will operate as a saw, and more readily cut through yielding substances

than such cutting tools as are formed of a more uniform substance.

This experimental enquiry directed my attention to a method of ascertaining the uniformity of texture in iron or steel, which perhaps may have been noticed by others, but is certainly unknown in most manufactories, though I have found it of great utility. If a weak acid, for example the nitrous, which I have usually taken in a very diluted state, be applied to the face of iron or steel previously cleaned with the file, or with emery paper, the parts which contain the greatest portion of carburet of iron (or plumbago) immediately shew themselves by their dark colour. It very frequently happens that articles of considerable value, intended to be fabricated in iron or steel, are not known to be defective until much expence has been laid out in manufacturing them. A piece of iron, which has a vein of steel running through it, as is too often the case, will require at least three times the labour and care to turn it in the lathe, which would have been demanded by a piece of greater uniformity. Steel which abounds with spots, or veins, or specks called pins, may be fashioned completely, and will not shew its defects, until the final operation when an attempt is made to polish it. Other articles, such as measuring screws, blades of sheers, fine circular cutters, &c. either bend in the hardening, from the difference of expansion, or resist the tool when wrought in the tempered state, or exhibit other incurable defects when they come to be tried; which the test by nitrous acid would have indicated before any expense had been incurred. In these, and in numberless other instances, it would have been incomparably more advantageous to have rejected the material upon the first trial, rather than have proceeded to the very expensive process of manufacturing the article and then finding it of no value. By this simple expedient I

have found bars of steel as full of veins and irregularities as wood, and have been enabled to select the best and most uniform pieces for works of the greatest delicacy; whereas, before I thought of this mode of trial, I have very often had the mortification to fail in the last stage of experimental processes, upon which much cost and labour had been bestowed.

Account of an Experiment to imitate the Damascus Sword Blades, in a letter from Mr. JAMES STODART, to Mr. NICHOLSON.

DEAR SIR,

Having lately had an opportunity of examining some sword blades, which appeared to be defective, I was induced to make the following experiment. The subject is surely of some importance, and perhaps never more so than at the present moment. We hear of swords having broken in battle, and we can hardly imagine a more distressing circumstance. Those which I have seen are certainly in no danger of failing in that way, for on the contrary they are evidently too soft, and consequently cannot form a good cutting edge. I am not acquainted with the process used in making sword blades, but am inclined to suspect that the price allowed, is not equal to the labour necessary to form a good instrument. The following method, which I believe to be nearly the same as that practised at Damascus, but which I suspect would be too difficult and expensive for general application, may perhaps lead to some more simple method of accomplishing the desired purpose. I took six small bars of good malleable iron, and the same number of sheer steel, and laid them one on another alternately, as if forming a galvanic pile; I then with the assistance of an expert workman, committed them to a clean forge fire, and with care we succeeded in welding them into a solid lump. This was

forged into a stout flat plate, which being heated to whiteness, was by means of strong tongs twisted spirally until it formed a cylindrical tube. In this twisted state it was heated, hammered flat, and again welded, and after being forged into a convenient form and substance, was doubled throughout its whole length, somewhat in the manner of the back of a saw. A slip of good steel was inserted, and another welding heat taken, which consolidated the whole mass. I need not say this slip of steel was intended for our edge. The remaining part of the process was simple; it consisted only in forging it into the shape of the blade we wanted; which on examination proved perfectly sound in every part. Being eager to witness some proofs of excellence and beauty which my expectation had anticipated, I too hastily and without due consideration proceeded to harden it by heating and quenching in water; and had the misfortune to see it cracking in seven or eight different places. I have no doubt this was occasioned by the unequal expansion and subsequent contraction of the different parts of the mass. In my next trial I shall guard against this accident. Enough however remained sound to prove it both good and beautiful; the edge bears the severest trials at the same time that the whole blade has sufficient tenacity. I have polished a part of it, and by applying a weak acid, produced an appearance, which though by no means equal to the beauty of what is called the Damascus water, leaves me little reason to doubt of accomplishing that appearance in my next trial. My intention is to multiply my pieces of metal, to repeat the process of twisting, and certainly not again to quench in water. I shall take the liberty to transmit to you an exact account of my next experiment, and if successful, to accompany it with a sample of the metal formed into a blade of some kind or another. I am with much respect, Your obedient servant,

J. STODART.

P. S. Why is the appearance produced on Damascus steel by the application of an acid called the water? Is it not different degrees of oxidation?* and what is the acid best fitted to produce this appearance. I had a paper given me some ten years ago on this subject, by a gentleman whose name I do not know. Unfortunately I have mislaid it.

In addition to what you have published on the subject in your valuable Journal, pray furnish us with any other facts that may have come to your knowledge since that period. The subject appears to me to be worthy of philosophical research, and perhaps of national encouragement.

Welding of Cast-Steel. By Sir THOMAS FRANKLAND, *Bart.*

The uniting of steel to iron by welding is a well known practice; in some cases for the purpose of saving steel; in others, to render work less liable to break, by giving the steel a back or support of a tougher material.

Ever since the invention of cast-steel (or bar steel refined by fusion) it has generally been supposed impossible to weld it either to common steel or iron; and naturally—for the description in Watson's Chemical Essays (vol. iv. p. 148) is just, that in a welding heat it "runs away under the hammer like sand." How far the Sheffield artists, who stamp much low-priced work with the title of cast-steel, practise the welding it, I am ignorant; but though I have enquired of many smiths and cutlers in different parts of the kingdom, I have not yet found the workman

* I have always supposed steel to be less readily soluble than pure iron; and that the carbon which is seen on the face of the former during the process of damasking, defends it from the acid, while the fibres of iron are etched by corrosion so as to exhibit the peculiar waving lines of this operation. N.

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Ever since the invention of cast-steel (or bar steel refined by fusion) it has generally been supposed impossible to weld it either to common steel or iron; and naturally—for the description in Watson's Chemical Essays (vol. iv. p. 148) is just, that in a welding heat it "runs away under the hammer like sand." How far the Sheffield artists, who stamp much low-priced work with the title of cast-steel, practise the welding it, I am ignorant; but though I have enquired of many smiths and cutlers in different parts of the kingdom, I have not yet found the workman

* I have always supposed steel to be less readily soluble than pure iron; and that the carbon which is seen on the face of the former during the process of damasking, defends it from the acid, while the fibres of iron are etched by corrosion so as to exhibit the peculiar waving lines of this operation. N.

who professed himself able to accomplish it. If therefore I should describe a simple process for the purpose, I may be of use to the very many who are incredulous on the subject. If any one has made the discovery on principle, he has reasoned thus: Cast-steel in a welding heat is too soft to bear being hammered; but is there no lower degree of heat in which it may be soft enough to unite with iron, yet without hazard of running under the hammer? A few experiments decided the question; for the fact is, that cast-steel in a white heat, and iron in a welding heat, unite completely.

It must not be denied that considerable nicety is required in giving a proper heat to the steel; for, on applying it to the iron, it receives an increase of heat, and will sometimes run on that increase, though it would have borne the hammer in that state in which it was taken from the fire.

I need scarcely observe, that when this process is intended, the steel and iron must be heated separately, and the union of the parts proposed to be joined, effected at a single heat. In case of a considerable length of work being required, a suitable thickness must be united, and afterwards drawn out, as is practised in forging reap-hooks, &c.

The steels on which my experiments have been made, are Walker's of Rotherham, and Huntsman's, between which I discover no difference; and though there may be some trifling variation in the flux used for melting, they are probably the same in essentials.*

* Mr. Pettibone of Philadelphia has succeeded in this process.

Of the CHEMICAL MANUFACTURES DEPENDANT UPON *Iron, viz.* GREEN COPPERAS: INK: PRUSSIAN BLUE: COLCOTHAR, CROCUS MARTIS.

COPPERAS.

Green copperas: sulphat of iron; is procured three ways, viz. from pyrites: from the precipitation of copper-water: from solution of iron directly in sulphuric acid.

First method. Pyrites, or sulphuretted iron, is found frequently in great abundance in strata of argillaceous shist; in England particularly, in the stratum superincumbent upon coal.

"The sulphuric acid dissolves iron, and forms the well known salt *Sulphat of iron; Green vitriol; Green copperas;* or *Sal martis.* The greater quantity of this salt which is used in manufactures of various kinds, particularly in dying black, is not prepared from the direct combination of its ingredients, but from various kinds of native sulphats of iron, or pyrites, after they have undergone spontaneous oxygenation by long exposure to air. Green vitriol is prepared in many counties in England; the first manufacture of the kind was undertaken in the reign of queen Elizabeth, at Deptford, where it is still carried on. It is likewise made largely in Northumberland and Durham. The method of manufacture is simple, and scarcely differs now from what it was more than a century ago as described by Colwall."

The following is the process actually in use.

"The usual mode of manufacturing copperas on the "rivers Tyre and Wear, is by exposing iron pyrites (there "called *brasses*) which are found in the collieries, to the "influence of the atmosphere. For this purpose a situa-"tion is chosen inclining towards the river, of a natural "strong clay. After the soil is taken off, gutters are cut "in different directions, and wells of about 5 or six feet

" deep, and two or three in diameter, are sunk where the " gutters terminate. Upon this surface the *brasses* are " laid to the thickness of 4 or 5 feet. The vitriolization " shews itself in a white efflorescence, which is washed " off by the rain into the gutters and conveyed by " pipes from the wells to a reservoir, from which there " is a pipe of communication to the boiler. This is " a leaden vessel generally about 7 feet deep, 12 to " fourteen long, and 6 or 7 wide, where the liquor is eva- " porated for 6 days, during which time a quantity of old " iron is added to it, as much as it will dissolve. It is then " run into a crystallizing vessel, and remains there for " five weeks, at the end of which time the mother liquor " is run into a reservoir, and pumped back into the boil- " er, and the crystals are removed, and after being well " drained are packed in hogsheads for sale. A single " boiling from a boiler of the above dimensions yields " from 5 to 8 tons of copperas, according to the strength " of the liquor."

Vitriol is made near Haguenau on the Rhine nearly in the same manner, according to the description given by Cavillier. The pyrites is disposed on an inclined soil in beds about two feet thick, beneath which are gutters going to a common reservoir. The vitriolization of pyrites is always seen by whitish efflorescences tasting strongly of vitriol, at the same time that the surface of the pyrites cracks in every direction. When the season is dry it is occasionally watered to carry off the vitriol already formed, and to promote a fresh vitriolization in the remaining ore. The heaps are found to be exhausted when these saline efflorescences are but scanty, and when the lump when broken appears changed throughout into the *liver pyrites.*

The vitriolic liquor is evaporated as usual in lead boilers, but it does not appear that old iron is regularly added

to saturate the liquor as in England, but only occasionally when it appears too acid. Some of the mother liquor of the former operation is always added.

The evaporated liquor before it passes into the crystallizing pools is sent to another bason, where it remains for twenty-four hours to deposit a large quantity of ochre. The crystallizing pools are made of fir planks surrounded with beaten clay. It requires ten days for the solution to deposit all its crystals, part of which is collected on sticks put into the vessel, but the purest vitriol is deposited the last. The liquor that remains after the deposition of the crystals (or the *mother-water* as such liquors are always termed) is reserved, and a portion is always added to the boiler in the next evaporation.

The vitriolization of the common pyrites used in these manufactures is a work of considerable time, more or less according to circumstances, but is generally several months before a bed is entirely exhausted. Vitriol is however also made in several places from *vitriolic peat*, and in this the process is much shorter. A large manufactory of vitriol from this source is carried on near Beauvais in France, thus described by M. Brisson.

The peat in the neighbourhood is of two kinds, the common combustible peat and the vitriolic. The former is, as in other countries, light, spongy, and full of visible remains of leaves, stalks, and vegetable fibres. The vitriolic on the other hand is easily distinguished by being heavier, harsher, and crumbly. The waters that run from it also deposit much ochre which readily detects the situation. The vitriolic peat is not found uniformly in any relative situation with the other species, but at different depths from the surface to about ten feet.

This peat is hardly exposed to the air before it opens of itself and becomes very dry and harsh, and soon heats even in small masses. To render the vitriolization more uni-

form and prevent the too drying effect of the sun, the peat is laid in heaps, only three or four inches in thickness under sheds thatched with straw, where they remain for a few days, after which they are ready for lixivation. This is done by throwing the peat into large vats of masonry and covering it with rain water, which flows through the heaps and is collected for the purpose, and also with some of the mother water of the former crystallization. It is then evaporated and crystallized in the method already described.

In some places the pyrites requires roasting before it can be decomposed by the action of the air. Thus at Geyer in Saxony, the pyrites, after being exposed for some time to the air, is soaked in water for twelve hours, then roasted as in the ordinary method of roasting ores, in a large bed upon faggots, on which about seventy or eighty quintals at a time are heated red-hot, and in this state plunged again into water. This is repeated six times successively with the same pyrites, by which the water becomes strongly impregnated with vitriol and is afterwards evaporated and crystallized as usual.

A quantity of heat is always generated during the process of vitriolization, both in the first combination of iron with sulphur and the subsequent oxygenation of the sulphur, and consequent conversion into sulphuric acid, which enables it to dissolve the iron and form the sulphat required.

The degree of the heat produced, and the quantity of moisture which the pyrites receives (by rain or other sources) are the circumstances that principally regulate the production of vitriol, both as to quantity and time of its production. Too much heat actually kindles the mass; the remaining sulphur takes fire, and an immense quantity of sulphureous acid vapour is given off to a great distance around. Where this takes place, little or no vitriol

is produced, for most of the sulphur and acid already formed is dissipated and also the iron becomes too much oxydated to yield the crystallizable salt. Hence it is dangerous and prejudicial to make too large heaps of pyrites or to put it up into stacks however preserved from the weather. Some moisture is also necessary to vitriolization, but too much of it keeps the pyrites too cold, and the process is languid. The iron added during the boiling is certainly useful, both as saturating the acid and encreaing thereby the yield of the salt, and also as precipitating by its superior affinity any copper which may arise from the admixture of copper pyrites, and also undergo vitriolization. In some manufactures however the admixture of a small portion of sulphat of copper is even an advantage, as in the dying of hats. (Aikin's Dict. I. 614)

Second method. In copper works, the sulphuretted ore of copper is roasted in ovens to drive off part of the sulphur. The ore is then washed. But as in the process of desulphuration, much of the sulphur is acidified by the oxygen of the air that supports the combustion, a sulphat of copper, or blue vitriol, blue copperas, is produced. When the ore is washed in water, that water dissolves the blue vitriol, from which the copper is precipitated by immersing bars and plates of iron in the solution. The copper thus precipitated is nearly in a metallic state; and when no more copper falls down, the iron is taken out, the precipitate collected for fusion, and the liquor which now contains sulphat of iron is evaporated to obtain that salt, which crystallizes in the usual way.

Third method. Oil of vitriol (concentrated sulphuric acid) is mixed with six times its bulk of water. Refuse iron is immersed in it till the liquor is saturated, and will take up no more iron. The clear liquor is gently evaporated and left to crystallize. One hundred parts by

weight of oil of vitriol, will yield 250 parts of chrystallized green copperas.

INK.

This is the gallat of iron, which turns black by exposure to oxygen, and then precipitates. The precipitate for the purpose of writing is suspended in water by means of mucilage of gum arabic. White sugar gives a gloss to the ink, but renders it more slow in drying. Hence it is an useful addition to copying ink.

I do not know a better composition for common ink than the following.

Logwood rasped or finely chipped, 1 ounce

Nutgalls in powder, 3 ounces

Green copperas calcined to whiteness, 1 ounce and a quarter

Blue copperas, ¼ of an ounce

Gum arabic pounded, 1 ounce and a half

White sugar, ½ of an ounce

Water one quart; vinegar one pint.

The vinegar and water should be poured hot upon the ingredients in a close vessel. When, cool it should be frequently stirred with a stick, for a fortnight. It may then be strained through a cloth, and put in a bottle.

Mr. Watt's receipt for the ink used for his copying press, and the preparation of the paper, is as follows.

Take a piece, or pieces, of thin paper which contains no size, or glue, or gummy or mucilaginous matter, or which at least does not contain so much size, or other matter, as would make it fit for being written upon. Cut this paper, or papers, to the size and shape of the writing of which a copy is wanting: moisten or wet the said thin paper with water, or other liquor, by means of a spunge or brush, or by dipping, or otherwise. Having moistened or wetted the thin paper, lay it between two thick

unsized spongy papers, or between two cloths, or other substances capable of absorbing the superfluous moisture from the thin paper; when it has been slightly pressed between such thick spongy papers, or other substances, by the hand or otherwise, lay the said thin paper, so moistened and pressed, upon or under the side of the writing which is to be copied, and in such manner that the one side of the said moistened paper shall be in contact all over the side of the said writing, so intended to be copied; and that, to the other side of the said moistened thin paper, there shall be applied a piece of clean writing-paper, or cloth, or other smooth uniform substance. Lay the said writing intended to be copied, with the thin moistened paper intended to receive the copy, (placed respectively as above directed,) upon the board of a common rolling-press, or of that of which a description and drawing are hereunder written and drawn, and press them once, or oftener, through the rolls of the said press, in the same manner as is used in printing by copper-plates; or instead of using the said or any rolling-press, squeeze the said papers, placed respectively in the manner above described, in a screw press; or subject them to any other pressure sufficient for the purpose: by means of which pressure, in whatever manner applied, part of the ink of the writing intended to be copied shall press from the said writing in to, upon, and through, the said thin moistened paper, so that a copy of the said writing, more or less faint, according to the quality of the ink and paper employed, shall appear impressed on both sides of the said moistened paper, viz.—Upon one of the sides in the natural or proper order and direction of the lines, as they are in the original writing, and on the other side in the reverse order and direction. But, in order to make the impression or copy of the writing more strong, legible, and durable, it

is proper and useful to moisten the said thin paper, which is to receive the copy or impression, with the following liquor, instead of water or other liquid, and to proceed in all other respects as is above directed; or to moisten the said thin paper with the following liquor, and to dry the said paper, and when a copy of a writing is required to be taken, the said paper, thus previously prepared and dried, ought to be moistened with water or other liquid, and to be proceeded with in all other respects as has been directed. The said liquor to be used for moistening the said thin paper, or for preparing the said paper previously to its being used, is made in the following manner: take of distilled vinegar two pounds weight, dissolve it in one ounce of the sedative salt of borax; then take four ounces of oyster-shells calcined to whiteness, and carefully freed from their brown crust, put them into the vinegar, shake the mixture frequently for four and twenty hours, then let it stand until it deposits its sediment; filter the clear part through unsized paper into a glass vessel, then add to the said mixture or solution two ounces of the best blue Aleppo galls bruised, and place the liquor in a warm place, shaking it frequently for twenty-four hours; then filter the liquor again through unsized paper, and add to it, after filtration one quart, ale measure, of distilled or other pure water. It must then stand twenty-four hours, and be filtered again if it shews a disposition to deposit any sediment, which it generally does. The liquor, thus compounded and prepared, is to be used as hath been directed.

N. B. In place of the vinegar, any other liquor impregnated with a vegetable acid may be used; and, in place of the galls, oak-bark, or any other vegetable astringent, or substance which is capable of becoming black or deep coloured, with solutions of iron; and in place of the oyster-shells, any other pure calcareous earth may be

used. But if the impressions are not wanted to be very black, and the writing-ink is good, water itself may be used to moisten the thin paper, as herein first directed. It may be found necessary to add more or less water, in the preparation of the above liquor to be used for moistening the thin paper, or to vary the proportions of the other ingredients, according as they are more or less perfect or strong, or as the impression is required to be more or less deep coloured. The writing ink which I use for letters or writings intended to be copied, is prepared as follows: take four quarts, ale measure, of spring water; one pound and a half avoirdupoise weight, of Aleppo galls; half a pound of green copperas or green vitriol; half a pound of gum arabic; four ounces of roach allum; pound the solid ingredients, and infuse them in the water six weeks or two months, during which time the liquor should be frequently shaken; strain the liquor through a linen cloth, and keep it in bottles, closely corked for use." Rep. Arts. 18.

Common ink may be made fit for records by grinding up with it about one sixth part of the weight of the copperas employed of calcined lamp black (the calcining in a close vessel improving the colour and rendering it less oily.) Or indigo, or Frankfort black, or even a very finely powdered charcoal may be substituted; or some common China or Indian ink may be dissolved in it. The liquid also should be half vinegar and half water, which sinks deeper, and the proportion of gum should be somewhat encreased.

I do not find that the directions of Van Mons, Desormaux, or Ribaucourt, offer any substantial improvement on the preceding recipe which is nearly Dr. Lewis's. The blue vitriol I add to give a blue tinge with the logwood: these two ingredients composing the false blue dye.

No experiments sufficiently decisive have been made on the preference that ought to be given to cherry or plum-tree gum, gum tragacanth, gelatine of flour, common glue, isinglass, or fish glue over gum arabic or gum senegal. Lewis says that all the vegetable gums answer nearly the same purpose, but that the animal glues do not. Of this I am by no means persuaded. Sour ale and water, makes a very glossy ink. If China or Indian ink be dissolved in a large proportion of water, the black sediment appears to be lamp black or ivory black, and the liquor putrefying, indicates that the colouring matter is suspended by animal jelly.

The preceding recipe for writing ink, contains more galls than are necessary to the highest degree of blackness, but not more than are necessary to the durability of the ink. For present purposes, one third of the galls may be omitted.

Common ink powder is thus made. Galls in powder two parts by weight; green vitriol in powder one part; gum arabic in powder one part; sugar one fourth of a part. These should be dissolved in water and vinegar, of which the latter may be in the proportion of one third, to the water.

A few cloves prevent the mouldiness of ink. I think cotton in an ink-bottle tends to preserve the colour.

As the fugitive part of ink is the gallic acid, old writings that have become illegible through time, may be rendered legible, by brushing them over with a solution of nutgalls in water; or by a dilute solution of prussiat of potash.

The colour of common ink is completely destroyed by oxymuriatic acid. This effect is counteracted by rubbing up some lamp black with the ink.

The ink of the ancients, was of the same nature with China or Indian ink, being made of lamp black (probably calcined to improve the colour and diminish the greasi-

ness) and suspended by means of glue. Their best glue was made by boiling bulls ears in vinegar and water.

China or Indian ink, can be washed off the paper by the patient application of a brush and warm water. Hence, Mr. Sheldrake has proposed a mixture of turpentine varnish thinned by oil of turpentine and coloured by lamp black. Or better by dissolving gum-copal in oil of lavender, and rubbing it off with a small quantity of lamp black. I have repeatedly dissolved gum-copal by means of gentle heat and much patience, in oil of turpentine, and oil of rosemary, and still more easily in oil of pennyroyal and oil of burgamot, and some other of the essential oils. This recipe may answer for some curious purpose, but it is not calculated for common use.

Red ink is made with cochineal and gum arabic dissolved in vinegar and water. Or by brazil, braziletto or nicaragua wood in the proportion of one ounce and a half to a pint of water, containing a quarter of an ounce of alum and half an ounce of gum arabic. *Blue* ink. Indigo and gum arabic. *Green* ink, dissolve in vinegar and water, crystallized verdigrease till the colour be sufficiently strong; thicken with gum arabic. *Yellow* ink; is made either by a decoction of saffron, or of French berries (grains d'Avignon.)

The common *marking ink* used for these thirty years in Manchester to mark the corners of the unbleached goods, is a solution of silver in nitrous acid, which when fused by fire, is the lunar caustic of the shops. Take of this one drachm, dissolve it in 4 times its weight of rain water: thicken it by putting in about half a drachm of gum arabic. Moisten the part you mean to mark, with a solution of one drachm of pearl ash in about six times as much water; dry it, and then write with the ink. This ink is used by the dyers and printers of cotton goods previous to bleaching, because neither acids or alkalies discharge the stain. But

for linen already whitened and made up, as shirts, table linen, &c. a solution of iron in nitrous acid thickened with gum arabic, is just as good: for although it may be discharged by the skilful application of acids, it will never wash out. Or a few drops of the nitrat of silver may be added to the nitrat of iron. The nitrat of iron does not require the previous use of the solution of pearl ash, as it is not so corrosive when fully saturated, as the nitrat of silver. If linen be marked with well-dyed blue thread, or with thread dyed a true turkey-red, no washing will discharge the colour.

PRUSSIAN BLUE.

The methods of making this pigment are kept secret in England and this country, I shall therefore present my notes on the subject with remarks on the processes I have collected.

I have repeatedly made it myself thus. Dry thoroughly in an iron vessel and powder grossly, any quantity of fresh blood. Dry thoroughly and powder also a quantity of pearl ash equal to the powdered blood. Mix them, and calcine them in a low red heat in a crucible with a loose cover until all smoke and flame ceases: then make the cover fit close, and calcine in a full red or nearly white heat for half an hour. The crucible should not be more than two thirds full, as the mixture is apt to swell. Empty the contents of the crucible into warm water in the proportion of a quart to four oz. of the mixture. Pour on again as much warm water: mix and filter the solutions. Dissolve of sulphat of iron (green vitriol) and of alum, of each a quantity equal to one half of the pearl ash employed. Pour the solution of alum and green vitriol mixt together, gradually into the solution of blood and alkali: both solutions are better for being warm, but not boiling hot. Stir it well. Let the sediment settle. It

will be of a dirty greenish colour: wash it. Then digest it for 2 or 3 days in diluted muriatic acid, (spirit of salt one part, water two parts.) The colour by this means gradually becomes blue, because the muriatic acid dissolves the yellow oxyd of iron which is not combined with the prussic acid. Wash it repeatedly. Dry it on chalk stones, paper, linen, or any other mode of draining off the water. Spread it thin to expose it to the air. I have kept the lixivium of blood and alkali (prussiat of potash) for a year and a half in bottles, and used it to make prussian blue with equal success as at first. Chippings of hoofs answer equally well with blood.

The more alum is put in, the more the colour is diluted, but it seems to be of use also, to save the muriatic acid.

In Philadelphia, hoofs and refuse cuttings of leather are calcined together with potash in a large iron vessel, but I do not know the proportions. My own experiments persuade me that more than one part or at the most, one part and a half of potash, to one part of animal charcoal by weight, is too much: but I believe the common proportion now is one part and a half of potash. The vessel in which the mixture of solutions is made, should be large, and the solution of copperas and alum gradually added, on account of the effervescence.

Another. "Heat the iron calciner red hot; then put into it one hundred weight of horns and 25 lbs. of pot or pearl ash, the horns will immediately begin to smoke violently; this inconvenience is considerably lessened by setting fire to the smoke with a bit of lighted paper, it will continue to burn at the mouth of the vessel for some hours. The fire is to be kept up or rather increased. In about two hours time, the horns will be considerably calcined, and must then be frequently stirred with an iron poker: after this has been continued for a length of time which is

much dependant on the degree of heat employed, the matter begins to make a considerable hissing noise, it is then to be constantly stirred until it becomes fused, then take it out of the calciner with an iron ladle and put it into any convenient iron vessel to cool. If the process has been properly conducted, it will appear in a cake of a dark dull green, the texture of which is much like liver of sulphur, Hepar sulphuris. This mass is to be broken in pieces, thrown into water and left in a covered vessel for two days to dissolve. 45 lbs. of alum and 15 lbs. of green copperas are dissolved in boiling water and left to settle. The clear liquor is decanted and made boiling hot, and the lixivium is likewise to be decanted and mixt with the other solution by putting alternately four parts of the alum and copperas liquor, to one part of the lixivium. The mixture is to be well stirred on each addition as an effervescence will take place, which without that caution would be likely to rise over the sides of the vessel. The prussian blue precipitates of a dark dull green, the liquor is then to be drawn off as close as possible, and more clean water added: the ablutions are to be repeated till the precipitate puts on the appearance of a very fine blue and is thoroughly edulcorated, which generally takes sixteen washings; it is then to be put on filtres, and afterwards to be dried on chalk stones.

(I have not noted my authority for the above receipt, but I believe it is from the relation of a manufacturer.)

Method of making prussian blue in Germany, by M. Baunach, Jour. de Ros. 1778, *part* 1, *p.* 312.

Take the horns and hoofs, of animals, the waste cuttings of leather, the latter in equal quantity with the former. Reduce them to small pieces, put them in a tubulated iron retort, and set this in a reverberatory furnace. Adopt a hogshead as a receiver: distill while any thing comes

over. The produce in the hogshead will be fetid oil, and volatile alkaline liquor. The residue in the retort is taken out, and broken to pieces. It is then put into an iron pot set in brick work and mixed well with three times its weight of potash. They operate commonly upon 10lbs. of the coaly matter, and 30lbs. of fixed alkali. The pot is heated gradually for an hour; then the heat is raised till the contents are fused. This operation lasts 12 hours, the matter is kept stirred all the time with an iron rod, when the matter thus fused gives out a smell of liver of sulphur, it is drawn red hot from the pot, thrown into water and boiled therein for half an hour. It is then poured off and fresh water boiled upon it to extract all the ley, which is filtered through cloth. Four parts of alum and one of green vitriol are then dissolved together and filtered. This is precipitated by the ley, and the precipitate left to dry.

Some manufacturers proceed thus. Take 6lbs. parings of skins, as much hoof and horns cut small: add 10lbs. potash: put them in an iron pot: let them macerate covered with water for 8 days, evaporate the water: put the mixture in a large iron pot, in which you have previously dissolved 2lbs. of crude tartar. Continue the fire till the substances are perfectly calcined: lixiviate. Then dissolve 5lbs. green vitriol and 15lbs. of alum water, and put this solution and the ley together.

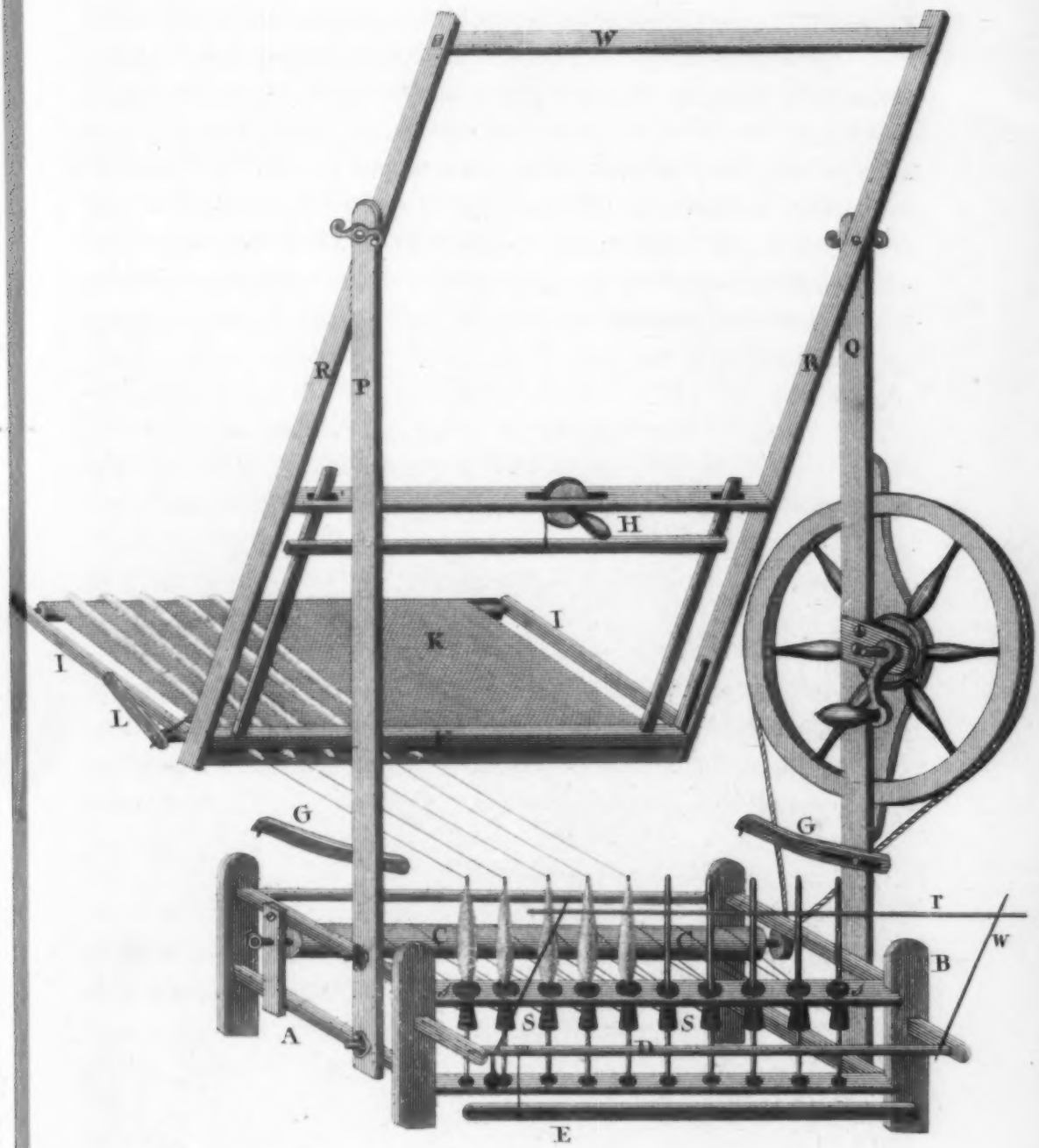
The objection I have to the above recipes, is that the quantity of alkali is too much for the animal matter, and the alum and copperas also in too great proportion, but they bear the stamp of actual processes. M. Baunach's method of saving the volatile alkali seems to be economical, but I doubt whether there be not a loss of prussic acid.

The cheapness of hoofs, horns, and leather clippings in Philadelphia, makes this manufacture a desirable one

acts as a traverse rod to distribute the yarn on the spindles as they are winding up; this rod is worked by the foot by means of a cord, near one end, wound round it, and descending to the foot-piece E, and is thrown back again by a small pea, or balance weight, near the connecting cord, when the pressure of the foot is taken off the foot-piece—P A, are upright posts which support the swing R R by two screw-pins, passing through the upper part of them. F is a clamp or slide, at the lower part of the swing, which slide is raised by turning the handle H and its pully, round which a cord passes and connects with the frame of the slide. I I, is a frame screwed to the sides of the swing, by iron straps, and carries two rollers, round which the feeding cloth K moves. The roller next the clamp, has a friction wheel at each end, and is supported by two levers L L, which work on pins at the sides of the frame I I; and are attached by strings, going from the front end of the lever, to the slides so that they rise and fall with it. G G are two gage stops moveable on the posts P Q, so as to set them to spin finer or coarser. W, is a counter balance weight of cast iron, to lessen the labour of throwing out the swing.—The size of a machine of ten spindles is about three feet long and two wide; the upright posts are six feet high; and the swing answerable to the other parts.

When the machine is to be used: the wool must be well carded into rolls, by a carding machine; and laid evenly on the feeding-cloth, with one end under the clamp or slide, which being fitted, by tongues into the grooves of the under part, holds the rolls firm. A small piece of the end of the rolls, next the spindles, must be drawn and twisted by the fingers, so as to tie them to the yarn on the spindles. Then with your right hand grasp the handle of the main wheel, and with your left the handle of the swing: turn the handle of the swing so as to raise the slide, which will press the friction wheels up against the gage-stops, and turn the front roller so as to bring forward the feeding cloth as you push out the swing; until the stops on the levers L L strike against the projecting part of the gage-stops G G, and prevent the swing from going out until you let the slide fall, which will confine the given length of the rolls. Before you proceed further to throw out the swing, gently turn the wheel, so as to give a slight twist to the roll to strengthen it for drawing: then with your left hand push out the swing, and with your right turn the wheel moderately, until you have drawn out the yarn to the

A perspective view of Dr. Allisons domestic Machine for spinning Wool.



Tribout & Lassence

length determined on for each stretch, and then give it the required twist. Previous to your returning the swing for winding up the yarn, gently turn the wheel, a very small distance backward, to unwind the yarn a little way from the spindle, then tread on the foot piece which will cause the traverse rod to distribute the yarn down the spindle so as to form your (torn) you are returning the swing with one hand, and the spindle with the other, to wind up the stretch that had been spun. When the foot is raised from the foot-piece, the pea, or small balance weight from the roller D, will return the traverse rod to its place.—Should a strand break in pushing out the swing, do not stop to mend it until you have returned the swing, and then tye it—A little practice will render the use of the machine familiar and easy——A child may be employed to piece the rolls.

NUTRITION OF VEGETABLES.

(Concluded from page 303.)

These experiments show the extreme facility, with which the oxydes of lead are reduced, and the obstacle that carbonic acid opposes to this reduction.

As these first attempts did not afford me the result I sought, I availed myself of an old experiment of Huyghens, who, in 1672, put some earth into a bottle, corked it up, and found it produce such a quantity of plants, as almost to fill the bottle, without having had any fresh air admitted to it. Accordingly I procured six large flint bottles, most of which were square: filled them in part with very fine white sand, which I deprived of all calcareous earth by washing with weak muriatic acid; and moistened this with distilled water. The remainder of the bottle was filled with atmospheric air freed from carbonic acid.

In these bottles having sowed 460 seeds of white mustard, I closed them very accurately, and placed them a few inches deep in a moist soil. Vegetation soon commenced, and considerable verdure was produced.* After six weeks growth my plants were

* It may be supposed, that these seeds did not germinate with as much vigour, as if in the open air. This however I do not think must be ascribed to the want of oxygen; for by trial of the air with a sulphuret before and

liberated from their prisons, washed with great care, and dried. In this state they weighed 9 gram. [140 grs.] I filled a phial with them, which terminated in a narrow tube, and exposed it gradually to a strong heat. Thus I obtained 4 grammes, 8 dec. [74 grs.] of coal. But as I supposed this coal might still contain a little sand, I incinerated it, and found 3 gr. 3 dec. [51 grs.] of alkaline ashes. Consequently there was 1½ gr. [23 grs.] of pure carbon.

In a very small vessel I distilled 460 white mustard seeds, and from this highly hydrogenated seed I obtained only 4 gr. [62 grs.] of coal, which lost near half its weight by calcination. Hence it follows, that 460 mustard seeds acquired in close vessels upwards of a gramme [15½ grs.] of pure carbon, which appeared evidently to have been formed at the expense of water, and probably of light.†

Geological facts too seem to shake that theory, which ascribes the carbon found in vegetables to the small quantity of carbonic acid contained in the atmosphere. How indeed can so small a portion of this acid, scarcely amounting to a ten thousandth

after the experiment, its proportions appeared to be nearly the same. This is agreeable to the experiments of Hassenfratz, who convinced himself, that plants do not diminish the quantity of oxygen in a confined atmosphere: and I am iniclined to think, that oxygen acts on plants merely as a stimulant, which is not indispensible, for Homberg found different seeds germinate in the vacuum of an air-pump. The principal cause that prevents the complete developement of plants in close vessels, appears to me to be owing to their abundant perspiration, which throws out the excrementitious fluids, that are so fatal to them even in the open air, as to render a certain space among their neighbours necessary to their vigorous growth.

† To satisfy myself, that plants can appropriate to themselves the elements of water, so as to constitute their different materials, only by their own organic action combined with that of light, I caused a given quantity of seed to grow in compleat darkness, and at the common temperature of the air. They shot out long white filaments, at the extremity of which were the two seminal leaves; but nothing more appeared. After desiccation these plants weighed less than the seeds whence they sprung: which appeared to be owing to their having lost carbon in this languishing state, instead of acquiring it.

But the mode of action of light on vegetables remains yet to be known. It appears however, that it enters into combination with them, and that to this combination is owing the green colour of their leaves, and the variety of hues admired in their flowers. Yet Mr. Humboldt has found green plants growing in deep and dark mines, the atmosphere of which contained

part of the air, explain the formation of those vast mines of pit-coal, which still retains the marks of those organized substances whence it originated, and the organic origin of which is sufficiently announced by its composition of carbon, hydrogen, oxigen, and azote? But without appealing to these ancient productions of the vegetable kingdom, buried in the earth in such abundance, we need only cast an eye on its surface, to satisfy ourselves that nature must have taken other steps to produce carbon.

On the other hand, if, in the silent progress of vegetation, the elements of water concur with the solar light to produce charcoal by intimate combinations unknown to us, charcoal ought to contain hydrogen likewise; and this is confirmed by experience.

If charcoal strongly calcined be urged in the fire with a substance that has an affinity for hydrogen, the charcoal is partly decomposed, and hidroguretted products are obtained. Mr. Berthollet mixed 30 gr. [460 grs.] of charcoal calcined in a forge fire with 20 gr. [309 grs.] of sulphur, and by distillation in a porcelain retort obtained more than 100 cubic centim. [391 lines] of sulphuretted hydrogen gas: and it appears to me to be probable, that if the experiment were frequently repeated with the same charcoal, it might be totally decomposed, a fact that it would be interesting to verify.

If oxigen in the state of gas be presented to the charcoal instead of sulphur, water is formed, as is proved by the experiments of Lavoisier on the combustion of charcoal, as well as by those of Mr. Hassenfratz: and analogous results are obtainable with metallic oxides, according to the observations of Cruikshank.

It even appears from the nice investigations of Messrs. Biot and Arrago on the refractive power of bodies, that the diamond, which has hitherto been considered as pure carbon, must contain a large quantity of hydrogen, which has the greatest refractive power of any substance yet observed in nature. These gentlemen intend to verify their conjecture by direct experiments, from which very interesting results may be expected. The existence of hydrogen in the diamond has been announced from other facts by Mr. Winterl.

From the chief facts that have been here mentioned, it follows:

a great deal of hydrogen. Does not this fact indicate something common between hydrogen and light, particularly when we observe, that these two fluids, the lightest in nature, seem likewise to produce analogous effects on some metallic oxides and salts?

1. That vegetables find in pure water every thing necessary for them to assimilate.

2. That vegetable mould in a state of compleat decay contains nothing soluble, and can only supply plants with water, which it retains abundantly in a certain state of division adapted to their nourishment.

3. That vegetables can grow in any substance, provided it have no action on them, and be perfectly insoluble in water.

4. That the organic powers assisted by the solar light, developes in plants substances that have been deemed simple, as earths, alkalies, metals, sulphur, phosphorus, charcoal, and perhaps too nitrogen, that probably will no longer continue to be the limits at which chemical analysis will stop.

5. That oxigen, hydrogen, and fire appear to be the only elementary substances, that serve to constitute the universe.

6. Lastly, that nature, in its simple course, produces the most various effects by the slightest modifications in the means it employs.

Machine for beating out Hemp seed and Flax seed, by Ezekiel Cleall. 23 *Nich. Jour.* 16.

SIR,

THE machine of which a model was sent to the society some months ago, must be used with eight flails, two on each arm, for beating out hemp seed.

When required to be used for beating out flax seed, the above eight flails must be taken out, and four beaters put in their place.

The height of the machine from the floor to the top of the board on which the flax or hemp is laid, is two feet; the breadth, two feet ten inches; the length of the board, four feet four inches; the length of each of the arms, from the axis of the machine, is three feet two inches; the flails for the hemp seed, two feet two inches long; the heights of the uprights, seven feet two inches; the beaters for the flax seeds, are each one foot three inches long, and seven inches broad.

The machine will thrash, in one day, as much hemp as grows on an acre of land, and other crops in proportion; and the work is

done with less than half the expense of thrashing in the usual way.

I am, Sir, your obedient servant,

EZEKIEL CLEALL.

Reference to the Engraving of Mr. Cleall's machine for beating out Hemp Seeds and Flax Seeds. Pl. II. *Fig.* 1, 2.

Fig. 1. Represents the machine for beating out hemp seeds, in which A is the table or board on which the hemp is to be placed; B the axis in which the four arms CCCC are fixed; DDDD, eight single flails, moving upon four pins near the extremities of the four arms; these flails diverge from the pins on which they move, so that two of them united on each arm are nearly in the form of the letter V. E is the winch or handle by which the machine is put in motion; F F, two upright pieces of wood to sustain the axle of the machine; G, an upper cross piece, to secure the uprights firm; H H, the two bottom pieces or sills, in which the two uprights are mortised, also the two smaller uprights which support the board or table A; I I, two lower cross pieces to secure the machine firmly; K K, two levers on which the table A rests, and by which it may be raised or lowered, as thought necessary, by iron pins, at K K, passing through these levers and the two uprights.

When the machine is used, the hemp must be laid on the table A, and moved about in different directions by the person who holds it, whilst another person turns the machine by the handle E; the flails D of the machine fall in succession on the hemp; as the axis moves round they beat out the seeds as different surfaces of the hemp are exposed on the table, and when the seeds are all beaten out from one parcel of hemp, a fresh quantity is applied upon the table.

Fig. 2. Represents one of the flax beaters, which is made of a solid piece of wood, one of which is attached instead of the two flails, to every arm, when the machine is employed for beating out flax seeds, as they require more force to separate them from the flax plant.

Machine for breaking Hemp, by W. Bond, Esq. of Canada. Ibid. 18.

In all new countries where labourers are scarce, we find many contrivances calculated for the purpose of reducing labour, more for the sake of expedition than ease; such, for instance, as the saw mill, the hoe, ploughs, scythe and cradle for cutting and ga-

thering grain, the wooden machine (drawn round by one horse) for thrashing grain, the iron shod shovel, drawn by oxen, and held by two handles, as a plough, for the purpose of levelling the roads, &c. Nor are the Americans, or other settlers in this country, fond of any work that needs violent exercise of the body; which the breaking of hemp in the old way certainly occasions, in consequence of requiring a cross motion of the arm, which makes the breakers complain of a pain about the short ribs on the side they hold the hemp; and on the opposite side a little under the shoulders, so that breaking of hemp in the old way is a great obstacle to its increased culture. To render labour, therefore, somewhat more easy and expeditious, is an object worthy the first attention, and I consider it practicable at a small expense, and have sent to the society, a model of a machine for this purpose.

I have observed among the clothiers' and fullers' machinery, great power and rapid motion proceeding from what is commonly called a dash wheel, erected across a stream of rapid water, the flies or float boards of which are fixed in the octangular axis, from fifteen to twenty-five feet in length, and from three and a half in depth, each fly. I have seen many corn mills in Upper Canada, with no other water wheels than such as the above described, which save a vast expense in raising dams, &c.

There are a number of streams in that part of Canada, which I have endeavoured to describe, (as to the practicability of the various ways of cultivation) that are well calculated for such wheels; and where these streams or rivers are not too wide, the axis of the wheel might be extended across so as to reach the land on each side, where I propose the breakers to be fixed to go by a tilt the same as a forge hammer. Such a simple piece of machinery would not cost more than 70 or 80 dollars, as little iron would be wanted, and timber we have for nothing; and when in motion would employ four breakers and two servers, from whom I should expect as much good work as fifteen or sixteen persons could possibly do in the old way, and that without much bodily labour.

Mills for breaking hemp, on the very same principle as that of a saw mill, as to motion only an addition of an iron crank, so as to run with two cranks instead of one, with something of a larger sweep than that of a saw mill, would be of vast utility in a neighbourhood of a large growth of hemp, and would not cost more than a common saw mill. As the breaks of the frame continue in motion the same as that of a saw mill, twenty men might be employed, who

Mr. Cleall's Machine for thrashing Hemp

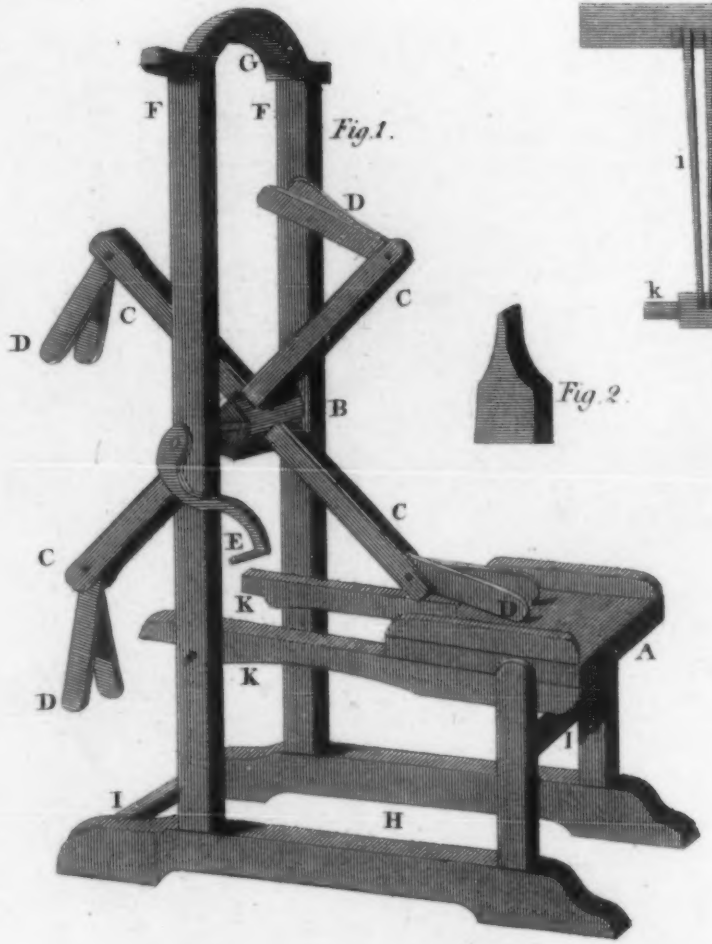


Fig. 1.

Fig. 2.

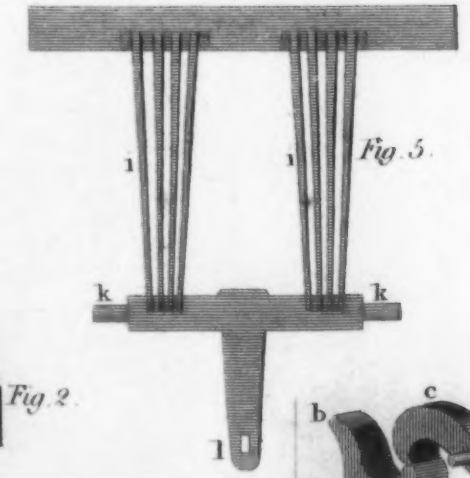


Fig. 5.

Mr. Bond's Machine for breaking Hemp

Fig. 4.

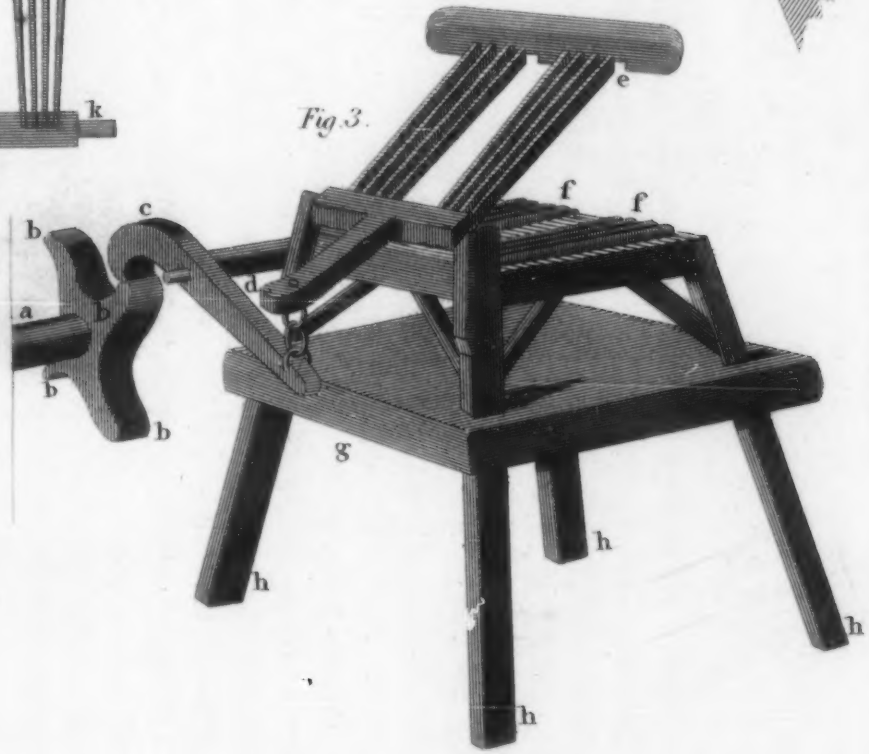


Fig. 3.

C. Tiebaut Sc.

would do as much as fifty or sixty could do in the old way, and with much more ease and pleasure to themselves; and this is not the only advantage that would result from such mills; it would cause something of a social meeting, which the youth would be particularly fond of. At such meetings all the defects respecting the culture and management of hemp would be examined into, and those who raised the best would become ambitious, and try to excel each other; thus we might reasonably expect, that Upper Canada would far exceed all other countries in the world for the growth of good hemp.

Reference to the Engraving of Mr. Bond's Machine for breaking Hemp. Plate. Fig. 3, 4, 5.

Fig. 3. *a* represents the axis of a water wheel, on which is fixed a trunnion of four lifters *b b b b*, each of which lifters raises in succession a lever *c*, which, by means of a chain connected with it, pulls down another lever *d*, and thereby raises the upper part of the double brake *e*. As each lifter of the trunnion passes the lever *c*, it allows the upper part of the brake to fall upon the hemp placed on the lower part of the brake *f f*; and by its weight, and teeth intersecting the teeth of the lower brake *f f*, the woody parts of the hemp plant are separated by repeated strokes from the filaments or fibres of the hemp proper for use. This completes the first operation necessary in the preparation of hemp. *g* is a table on which the woody parts of the hemp fall, and which gives security and strength to the frame; *h h h h* are the four legs or supports of the frame.

Fig. 4. shows a section of the teeth of one half of the double brake above mentioned: it is betwixt the upper and lower rows of these teeth that the breaking of the hemp takes place, by the repeated rise and fall of the upper part of the brake upon it.

Fig. 5. shows the upper part of the brake, in which *i i* shows the two rows of teeth, *k k* the two pins on which it is moved, *l* the part to which the chain which raises the upper part of the brake is attached. After the breaking of the hemp, it is wholly finished for use by scutching or swingling, an operation which may be either performed by the hand or machinery, and is easily executed by either mode.

The machinery for breaking hemp should be removed from the rivers previous to the beginning of the frosts.

COAL GAS.

It is now ascertained in England, that manufactories can be lighted cheaper, more conveniently, more neatly and more safely, by means of the inflammable gas from pit coal than by any other means. I do not believe that the act of extracting and burning this gas, is in a state sufficiently advanced as yet, to render it eligible for lighting dwelling houses. But the manufactories of New-England, of Philadelphia, of Pittsburgh, may use it with profit—it may be used for theatres——and (as I am persuaded) for a great deal of the kitchen-cookery of large taverns in summer time. It has not yet been applied in lieu of steam, as a moving power in fire-engines, but I think it will be.

In this country, every suggestion that brings forward the importance of COAL to the public view, is of moment: we know little of its value in Pennsylvania as yet. *All, all*, the superior wealth, power, and energy of Great Britain, is founded on coal mines. Coal mines produce manufactories; manufactories produce canals, turnpike roads and rail ways; these produce communication of interest, knowledge, and improvement all over the kingdom. Where coal mines are, there, and there only will manufactories flourish. Manufactories produce division of labour, corporal and mental energy; they banish idleness; they produce perpetual demand for, and bring into play chemical science, and the science of machinery. They have produced a class of men almost peculiar to England, the *civil engineers*, to whom the country has been more indebted than to any other class of citizens, dependant on their talents for their living. All rests upon coal.

Coal may be classed under two great divisions: the coal that burns with smoke and flame, bituminous coal: and the coal that does not burn with smoke and flame: stone coal, glance coal, anthracite, graphite coal. All the coal to the west of the west branch of the Susquehanna, is *bituminous* coal; this will yield abundance of carburetted hydrogen gas, and will charr or coke. The coal east of the north east branch of Susquehanna, burns without smoke, with little flame, contains no bitumen, abounds in carbon, and is an *anthracite*.

I present the reader with the two most approved methods of obtaining the inflammable carburetted hydrogen from pit coal.

Description of an Apparatus for making carburetted Hydrogen Gas from Pit Coal, and lighting Manufactories with it. By Mr. SAMUEL CLEGG, *of Manchester.* 23. *Nich. Jour.* 85.

DEAR SIR,

When your son was in Manchester, he called to see my nephew, Samuel Clegg's improved gas lights, and was desirous to have a plan of his method, which my nephew promised him, and I undertook to get it conveyed to you, I have accordingly, taken the opportunity of sending to the Society of Arts a plan and explanation of his apparatus.

He lighted a large manufactory in Yorkshire some years ago upon this principle, and has since lighted some buildings in this neighbourhood, and I believe he is the first person, who succeeded in rendering these lights free from the offensive smell which generally accompanies them. My nephew served an apprenticeship to Messrs. Boulton and Watt, of Birmingham, in the steam engine business, in which he is now engaged here on his own account, and has made considerable improvements in their construction.

I remain, dear Sir,

Your most obedient servant,

ASHWORTH CLEGG.

Manchester, May 18, 1808.

SIR,

Your esteemed favour I have received, and, according to your request, have sent you a fuller explanation of the gasometer and lamp, accompanied with farther drawings.

A gasometer, containing seven hundred cubical feet of gas, weighs about twenty hundred weight, and costs about two pounds ten shillings the hundred weight.

The whole of an apparatus complete, capable of supporting forty lamps for four hours, each lamp affording light equal to ten candles of eight in the pound, will cost about two hu ndred and fifty pounds. Each lamp consumes six cubical feet of gas per hour. I am happy to find, that the Society have honoured my communications with their attention, and I remain, with great respect,

SIR,

Your most obedient servant,

S. CLEGG.

Manchester, Aug. 12, 1808.

Reference to Mr. S. Clegg's Apparatus for extracting Carburetted Hydrogen Gas from Pit Coal. See Plate. figs. 1, 2, 3, 4, 5, *and* 6.

In fig. 1, A shows the cast iron retort, into which are put the coals intended to be decomposed by means of a fire underneath it, the heat of which surrounds every part of it, excepting the mouth or part by which the coals are introduced. The lid or iron plate B, which covers the mouth of the retort, is ground on, air tight, and fastened by means of a screw in the centre; C is a shield or saddle of cast iron, to preserve the retort from being injured by the intensity of the fire underneath it, and to cause it to be heated more uniformly. D D D represents the cast iron pipe which conveys all the volatile products of the coal to the refrigeratory of cast iron E, in which the tar, &c. extracted from the coal is deposited, and whence they can be pumped out by means of the copper pipe F. G is the pipe which conveys the gas to the top of the cylindrical vessel or receiver H; this receiver is air tight at the top, and consequently the gas displaces the water in the vessel H, to a level with the small holes, where the gas is suffered to escape and rise through the water of the well I, into the large gasometer K. The use of the vessel H is pointed out as follows, viz. If the pipe G reached all through the water, without passing into the vessel H, the gas would not be rendered pure or washed: and if part of the pipe did not rise above the water, the water would have free communication with the tar, besides exposing the retort A to a very great pressure, so as to endanger its bursting when red hot. This vessel or receiver H, in a large apparatus, is about eighteen inches diameter, and two feet long: the quantity of gas therefore which it contains, is sufficient to fill the pipes and retort when cool, prevent the pipe G from acting as a siphon, and expose the gas to the water without endangering the retort.

When the operation begins, the upper part of the cylindrical gasometer K, fig. 1, made of wrought iron plates, is sunk down nearly to a level with the top of the circular well I, and is consequently nearly filled with water, but it rises gradually as the gas enters it and displaces the water; the two weights L L suspended over pullies by chains keep it steady and prevent its turning round, otherwise the lower stays M of the gasometer would

Coal Gas Apparatus.

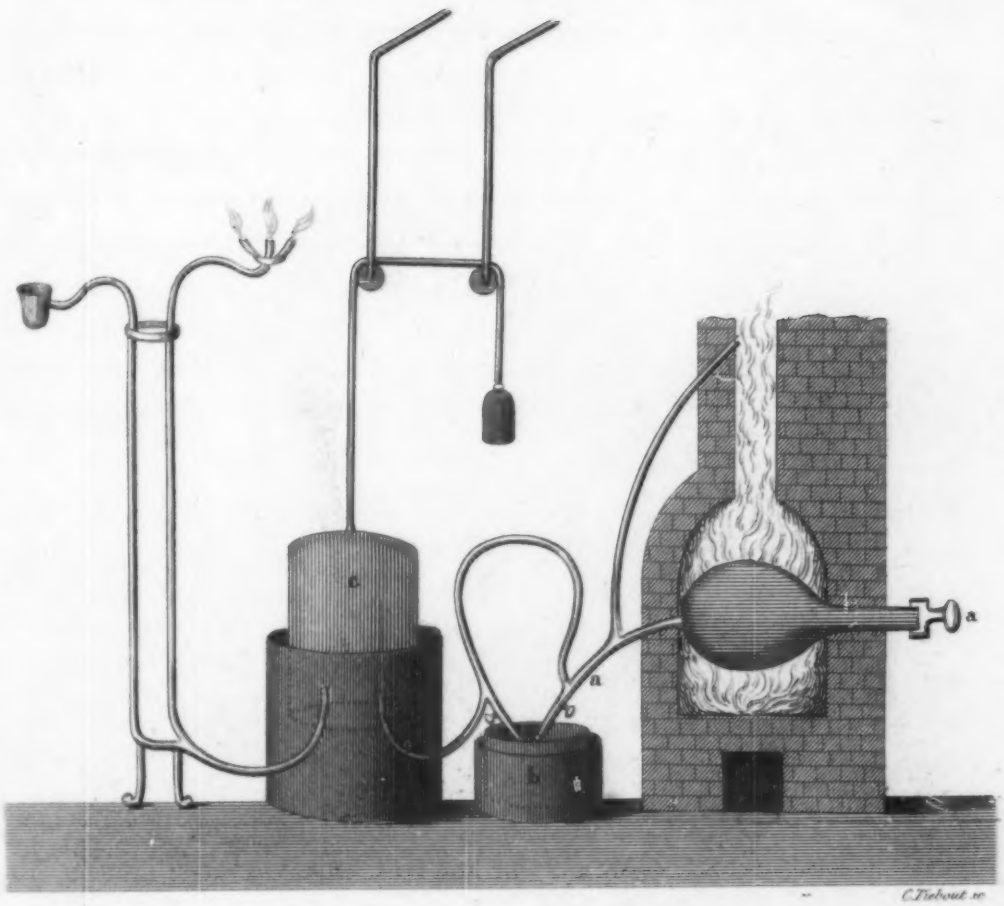
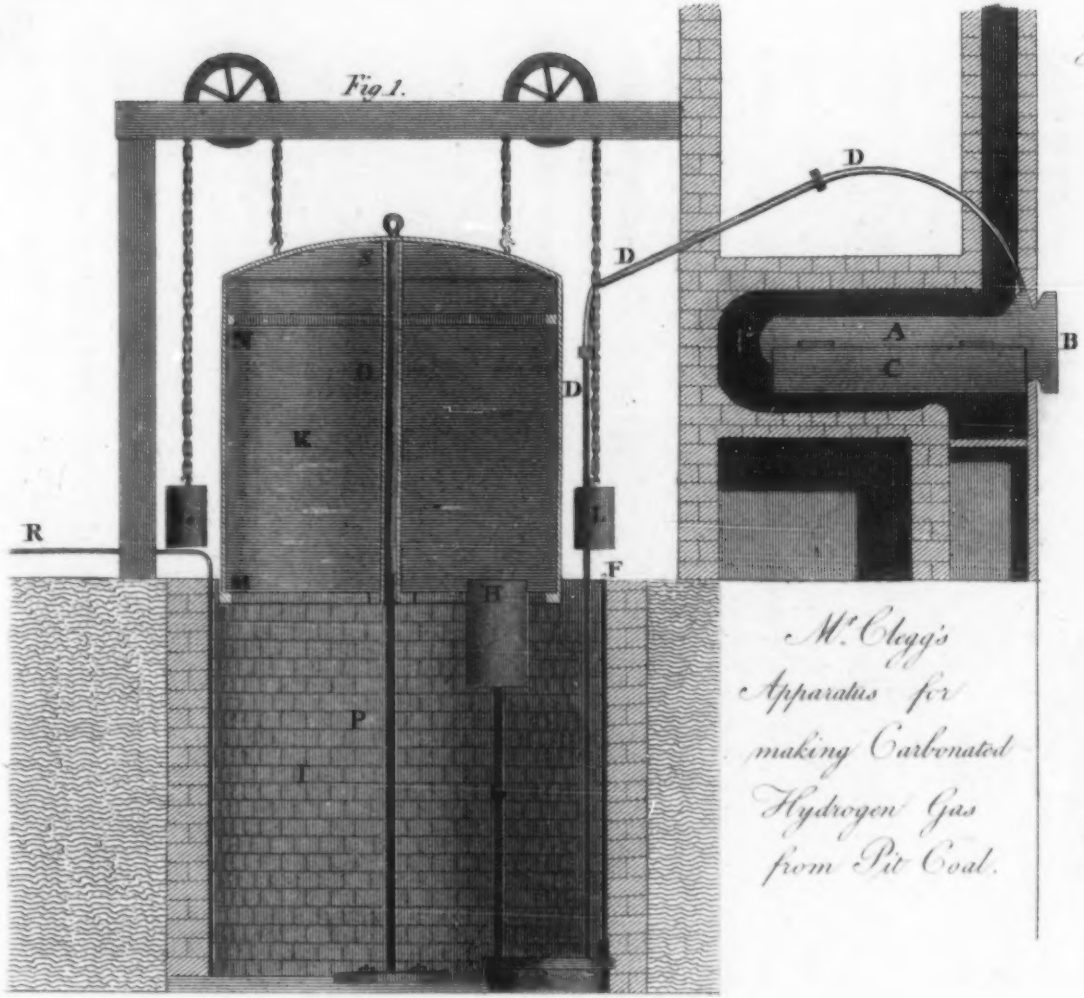


Fig. 1.



Mr. Clegg's Apparatus for making Carbonated Hydrogen Gas from Pit Coal.

Horizontal Section of the Gazometer at the bottom part

Fig. 2.

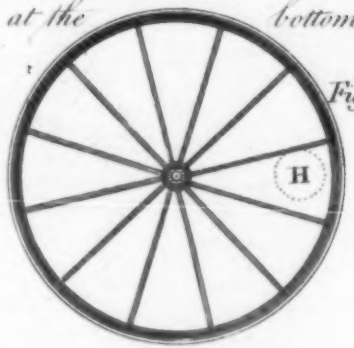


Fig. 4.

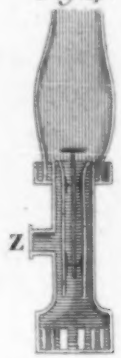
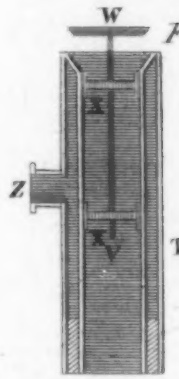


Fig. 5.



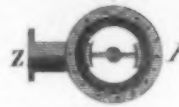
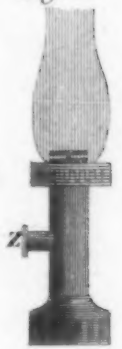


Fig. 6.

Fig. 3.



come into contact with the vessel H. There are two sets of these stays, one shewn at M, and the other at N.

There is also an iron pipe O, made fast in the centre of the gasometer by means of the stays, which slides over the upright pipe P, by which contrivance the gasometer is kept firm and steady, when out of the well; it likewise prevents the gas from getting into the cast iron pipe P, and the copper pipe R, any where but through small holes made in the pipe O at S at the top of the gasometer, where the gas is perfectly transparent and fit for use.

The pure gas enters the tube O at the small holes made in its top at S, and passes on through the tubes P and R to the lamps, where it is consumed and burnt.

The seams of the gasometer are luted to make them air tight, and the whole well painted inside and out, to preserve it from rust.

Fig. 2, shows a horizontal section of the lower hoop of the gasometer K at the part M, with its stays or arms, and the manner in which the iron pipe O, before described in fig. 1, sliding on the tube P, passes through the ring in the centre of the hoop. A horizontal section of the receiver H appears therein.

Fig. 5, shows a section of one of the gas lamps. The space between the outer tube T and the inner tube V, is to be filled with gas supplied by the pipe R, shown in fig. 1, where a stop cock is inserted for adjusting the flame, which gas passes through a number of small holes made in the outer edge of a circular plate shown at fig. 6, which unites the tubes T and V at their tops. V is the inner tube which conveys the atmospheric air into the centre of the flame: the upper part of this tube is made conical, or widening outwards, to join a circular plate with holes in it, a horizontal view of which is shewn at fig. 6. W is a button, which can be placed at a small distance above the mouth of the lamp, and its use is to convey, in an expanded manner, all the air which rises through this tube to the inner surface of the flame, which assists the combustion very much; this button may be set in any convenient distance above the tubes of the lamp, as it slides in the cross bars X X, by which it is supported in the inner tube.

A current of air also passes between the glass tube or chimney and the outer tube T, through holes made in the bottom of the glass holder, as in Argand's lamps: this surrounds the flame, and completes its combustion, as explained by the view, fig. 3, and

section, fig. 4, which have a glass upon each. Z Z Z Z, figs. 3, 4, 5, and 6, show the tube through which the lamp is supplied with gas from the pipe R, fig. 1.

Another apparatus for coal gas. Park's Chemistry. Plate.

The retort is filled and the cork taken out at D, which should be four inches diameter stopt with an iron plug. The tar and liquid partly runs down the tube with a stop-cock, next the furnace, but some of it mounts with the gas, and being cooled in the bent part of the tube runs down at the second tube with the stop-cock into the barrel B, which is inserted in an outermost barrel, and surrounded with water to condense the contents. The gas-holder C is suspended with its balance weight from the cieling. The rest is obvious. The gas holder and its containing vessel may be tin, copper, sheet iron, or simply casks. The perpendicular tube that rises into the chimney is designed to carry off the carbonic gas and water which rise at the beginning of the process, and which if mixed with the carburetted hydrogen would hurt the combustible quality of the gas sought for. Quere if a stop cock at D would not be useful for the first five or ten minutes? The tubes may be lead, tin, or copper.

The distilled products will pay a great part of the expense.

ON MINERAL WATERS,

And watering places: particularly the Carlisle and York Springs in Pennsylvania, with a method of making artificial mineral water—By the Editor.

The resort to these situations, is partly on account of ill health, and partly for the sake of amusement, company, and variety. In England, on the continent of Europe, and in this country, the various motives of frequenting mineral springs are the same; and fashion is given to them, and medicinal virtues ascribed to them, rather by the votaries of pleasure, than the valetudinarian visitors. I do not pretend to deny, that laxative and tonic salts in small doses are frequently beneficial; but far more of the cures such waters are said to perform, are owing to good society, good scenery, amusement, novelty, change of air, incitements to pleasurable exercise without fatigue, and though last not least, to faith in the effi-

cacy of the waters. All these circumstances are TONIC, and in a high degree so. No wonder, that large dilution, frequent exercise, and moderate doses of laxatives should occasionally do wonders to an invalid, whose digestive powers suffer under the indirect debility consequent upon habitual over action, and who has all the confidence necessary to enable the medicine to cure.

In the neighbourhood of Carlisle there are two mineral springs, resorted to greatly by persons in good health and in bad health; and of the one and the other wonderful stories are propagated in favour of their beneficial effects upon complaints of almost all descriptions. I have analysed these waters, and I proceed to give an account of them.

The *Cumberland Sulphur Spring*, on the estate of Wm. Ramsey, Esq. Prothonotary of this county, is situated about 5 miles north easterly from Carlisle. Carlisle is situated in the Cumberland valley; a limestone valley extending from Easton, on Delaware, through Cumberland county, Shenandoah, and southward beyond Staunton, in Virginia. About three miles from Carlisle, on the road to the sulphur spring, runs the Conodoguinet creek: half a mile before you come to this creek, the limestone disappears, and the surface soil is a schistus or rather a shale which extends from thence to the spring, and from thence to the north mountain as it is called, or the blue ridge. The spring is in a direct line not quite a mile from the mountain. The surface-stone of the neighbourhood, is mountain quartz, amorphous, striking fire with steel. The well belonging to the house, is dry through 14 feet of shale, such as is frequently incumbent on coal. There is no trace of limestone in the immediate neighbourhood.

The spring rises near a stream of good water; the quantity in summer time is such as would run with moderate velocity through a pipe of about half an inch bore. It smells and tastes strongly of a sulphureous gas, but has no other flavour or odour. The temperature is that of the common spring water. It feels soft and smooth to the hands on washing with it.

About three pints of this water boiled, yielded about one half its bulk of gas. This gas tastes and smells strongly of sulphuretted hydrogen: it deposits sulphur with oxymuriatic acid. The water itself blackens silver: it discharges the blue colour of muslin tinged with litmus: it discharges also in a great degree the colours of printed calicoes washed in it. It is therefore impregnated with sulphuretted hydrogen, holding sulphur in solution; and pro-

bably also with sulphuret of potash. From the experiments of Higgins and Kirwan, we know that alkaline and calcareous sulphurets are useful in bleaching.

Tincture of galls, and triple prussiat of potash, produced no change; it therefore contains no iron.

Oxalate of ammonia, hardly afforded a perceptible cloudiness. It therefore contains but little lime.

Carbonat of potash, threw down no magnesia: nor did carbonat of ammonia throw down any alumine, or the addition of phosphat of soda, exhibit any magnesia.

Nitrat of silver occasioned no precipitate; hence the water contains no muriatic salts.

Acetite of lead, produced a precipitate tinged blackish: indicating a sulphuret of potash or of lime.

Muriat of barytes detected no vitriolic acid combined or uncombined. The colour of litmus-rag, was not changed either blue or red; so that there appeared to be no uncombined acid or alkali:

A pint of the water gently evaporated to perfect dryness, in a queens-ware basin, by means of a spirit lamp, yielded barely 2 and $\frac{1}{3}$ grains of deliquescent residuum; which was half potash and half lime, both manifestly distinguishable to the taste, as well as by tests. This was repeated in Florence flasks, with the same results. These salts had doubtless been combined with sulphur.

Hence, the water in question, is water more pure than common, in every respect, except in holding half its bulk or there about of sulphuretted hydrogen gas, to which alone its medicinal properties are owing; for the very small proportion of alkalies and lime combined as sulphurets with the sulphuretted hydrogen water, cannot be regarded as producing much effect. The weather had been rather wet for about a week or fortnight preceding the time when the water was taken up; but there had been no rain for 3 or 4 days; nor did it seem, that the water was either more or less abundant than usual. So that the preceding experiments may be considered as made on the water, in its average state.

I conjecture, that the sulphuretted hydrogen, is produced by the decomposition of pyrites, deposited in the shale forming the roof of a coal stratum; though no trace of coal has hitherto been found or suspected in that neighbourhood. In many counties of England, the pyrites found in the roof of coal and the superincumbent stratum, is collected, placed in heaps exposed to the

air, and the green vitriol or sulphat of iron gradually formed by the oxygenation of the sulphur is washed off, and crystallized. Where sulphuric acid thus formed acts upon sulphuretted iron, sulpheretted hydrogen will be produced, and escape through any sinus or aperture in the earth, where there is room for it, whether in contact with water or not. Where there is no stream but moisture only, pyrites will become hot, if air can get to a body of it, and that heat may be communicated to the earth and the capillary streams in the vicinity of it, forming the warm waters, of Bath, Matlock and Buxton, of England, and the warm springs of Virginia.

In point of situation for *salubrity* of air, I know of no watering place in Pennsylvania that upon the whole, equals the sulphur springs in the vicinity of Carlisle, excepting the fashionable resorts on the sea shore.

The York sulphur springs, 17 miles from Carlisle, on the road to Baltimore through Hanover: are found in a transition country. I have remarked in the vicinity of the spring, much amphibolic rock (hornblend and quartz.) Amphibole upon the average contains about a twentieth of magnesia.

Dr. Cutbush analysed this water a year ago: he found that alcohol of galls, prussiat of potash, and succinate of ammonia produced no appearance of iron.

Muriat of barytes, produced a precipitate of sulphat of barytes.

Lime water, shewed no trace of carbonic acid.

Nitrat and sulphat of silver produced a muriat of silver.

Solution of soap produced a turbidness, shewing generally the presence of saline matter, oxalat of potash, threw down an oxalat of lime.

Caustic and carbonat of potash, threw down earthy matter soluble in muriatic acid; that is lime and magnesia.

Ammoniaco-phosphat of soda, threw down an ammoniaco-phosphat of magnesia. The quantity of gas contained, he had no opportunity of examining: but there is no doubt of its being sulphuretted hydrogen, nearly, but not quite so strong to the smell or the taste, as the water of the spring within five miles of Carlisle. It blackens silver like the latter water.

Dr. Cutbush on evaporating two ounces of the water, found a residuum amounting in sixteen ounces or one pint, to thirty two grains of saline matter: this would consist of 20 grains of epsom

salt or sulphat of magnesia, 4 grains of common salt or muriat of soda, 6 grains of gypsum or sulphat of lime; loss 2 grains.

I received toward the latter end of July two quarts of this water, from the spring; and as much from the pump; which latter I did not analyse. There had been rainy weather for some days, with an interval of 4 or 5 fine days immediately previous to the water being sent to me.

The water from the spring being tested with the same reagents employed by Dr. Cutbush, exhibited the same general appearances and indications, except that oxalat of ammonia threw down but a slight trace of lime.

Sixteen ounces avoirdupois, of the water carefully weighed, being evaporated, yielded not quite five grains of saline matter: this was repeated, in white queen's ware, and in florence flask, by means of the gentle evaporation of a spirit lamp: hence it should appear, that the water of this spring, is variable in the quantity of saline matter it contains.

The saline matter from these evaporations was reduced to fine powder, and a part thrown on a well lighted coal: there was no appearance of deflagration, and therefore there were no indications of nitrats.

On barely 5 grains from a pound of the water, finely triturated, I poured strong spirits of wine: this dissolved the muriats, and left behind the sulphats.

I boiled for a minute, the sulphats in pure water barely sufficient in quantity to dissolve them: this would separate the sulphat of soda, and the sulphat of magnesia. The residuum being dried into white silky crystals, was manifestly sulphat of lime; amounting to barely two grains in weight.

The alcoholic solution containing the muriats, was precipitated by nitrat of silver, and yielded about a grain of muriat of silver, indicating $\frac{1}{3}$ of a grain of pure muriatic acid: the nitrated solution precipitated by carbonat of potash, yielded about $\frac{1}{4}$ of a grain of precipitate, which readily dissolving in a minute portion of diluted sulphuric acid, and remaining permanently clear, was not lime, but carbonat of magnesia.

The solution of sulphats, precipitated by carbonat of potash, yielded also barely one grain of carbonat of magnesia. The remaining liquors would contain a grain or thereabout of alkaline sulphat which I did not think worth while to ascertain minutely.

The water of these springs, as is said, are diuretic, and of the

York spring, purgative. I could never find any effect of either kind, from a quart of these waters, or the waters of the Bedford springs, beyond what a quart of common water would produce; and I am well persuaded that the common pump water of the streets of Carlisle (which leave a residuum of 7 grains to the pint) and still more those of Philadelphia, according to my friend Dr. Hunter's analysis, contain a larger portion of cathartic ingredients than the waters of either of these medicinal springs.

Even according to Dr. Cutbush's analysis of the York spring water, one pound weight contains but 24 grains of purgative salt, for gypsum is not usually ranked in this class. That is 20 grains of epsom and 4 grains of common salt.

Now, the common dose of glauber's or of epsom salt when used as a cathartic is $1\frac{1}{2}$ oz, or 720 grains: less than a fourth of this dose, or 180 grains, can hardly be deemed a permanent laxative: but to obtain this laxative quantity, near eight pints or eight pounds weight of water must be swallowed! Doubtless, if a man pours down his throat within 2 or 3 hours, a gallon of water of any kind, it must find its passage out again, either by diuretic, cathartic, or diaphoretic operation, or by all.

Still the fact is, and it is not to be denied, that people who stay two or three weeks at either of these springs, generally come away with improved health, provided they use exercise, dilute a good deal with the water, and live abstemiously in the articles of wine and ardent spirits. This may be accounted for

From the beneficial effect upon the skin particularly of the sulphuretted hydrogen gas; which certainly possesses virtues in cutaneous affections: nor are we as yet fully aware how much the general state o. health depends on the state of the skin.

From the temporacy cathartic effect in a slight degree, which change of water frequently induces.

From the tonic effects, of change of air, change of society, change of scenery, change of amusements, from having the mind and the body pleasantly occupied, and from comparative temperance and great dilution among the male part of the society.

From early rising and the use of the bath, warm or cold, these are causes sufficient to account for all the beneficial effects received, without resorting to supposed ingredients or supposed qualities in these waters, which experiment carefully made, does not countenance. T. C.

A week after the preceding analysis, during which interval the weather had been fine and warm at the latter end of July and beginning of August, I received more water from the York springs. I evaporated carefully 2lb avoirdupois. I collected 14 grains of saline matter. It was dried, triturated, dissolved in alcohol, and the residue in hot water. The last watery solution, left a residuum of six grains, which was fully dried over a lamp, and proved to be sulphat of lime. To be quite sure of this, it was decomposed by double its weight of carbonat of potash. The sulphat of potash washed away, left the carbonat of lime perfectly soluble in dilute muriatic acid except about the $\frac{1}{4}$th of a grain of siliceous sand.

The water in which the sulphats were dissolved, had taken up a small portion of the sulphat of lime, which oxalat of ammonia detected, amounting to about $\frac{1}{3}$ a grain, there being one grain of oxalat of lime. The sulphuric acid was combined with potash as the crystals shewed: it was precipitated with barytes; and produced two grains of sulphat of barytes, dried over a lamp.

The alcoholic solution of the muriats furnished me with $1\frac{1}{2}$ grain of muriat of silver, $\frac{1}{4}$ a grain of alumina, and about $1\frac{1}{2}$ grain of carbonat of magnesia. As an accident happened to part of the filtering paper, on which this was dried, there *may* be an error of half a grain here, but I believe there is not an error to half that amount.

Hence the sulphur spring, 5 miles from Carlisle, contains in one pint by measure or 1lb by weight, about $\frac{1}{2}$ its bulk of the gas called sulphuretted hydrogen. It contains also one grain of pure potash united to sulphur, and as much pure lime, also combined with sulphur.

The sulphur spring, in York county, 17 miles from Carlisle, contains probably about as much sulphuretted hydrogen as the spring near Carlisle; but as the gas will not bear transportation, I have not the means of accuracy in this respect.

The York spring also contains in one pint by measure, or 1lb. by weight, according to the first experiment 5 grains of dried saline matter: yielding 2 grains of sulphat of lime, $3\frac{1}{3}$ grains sulphat of magnesia, about $\frac{1}{2}$ a grain of muriat of magnesia, and one grain of sulphat of potash. The excess above the five grains in this calculation, will arise from the greater quantity of water of crystallization in these salts in their common state, than in the dry state, in which I procured them. Thus, one grain of carbonat of magnesia is equal to ,65 of a grain of pure magnesia, which would make

four grains of crystallized sulphat of magnesia: for sulphat of magnesai contains 33,05 acid, 16,05 magnesia, and 50 water.

According to the second experiment one pint or 1lb. of the water, yielded seven grains of dried saline matter: which when fully crystallized, would yield nearly as follows:

Of sulphat of lime (gypsum) $4\frac{1}{2}$ grains.

Of sulphat of potash $2\frac{1}{4}$ grains.

Of muriat of magnesia $1\frac{1}{2}$ grain.

Of muriat of alumine $\frac{1}{4}$ of a grain.

Hence not only the quantity, but the proportions of the salts in these waters, is apt to vary; owing in great part to the different states of decomposition of the amphibole, and other stones, through which the waters pass, as well as to the wetness or dryness of the season.

The common pump water of Carlisle furnishes 7 grains to the pint of dried saline matter consisting chiefly of sulphat and carbonat of lime. It is apt for a few days slightly to affect the bowels of strangers not accustomed to limestone water.

The best method of combining the Seltzer water with a laxative proportion of the purgative salts is the following; which will enable every body to make at will, a mineral water, impregnated with cathartic qualities in any proportion that the palate will bear or the bowels will require, combined with the lively, sparkling qualities of the Seltzer water. Take of supercarbonat of soda, or even the common carbonat 20 grains; of the common carbonat of magnesia as much, put them in a strong black quart bottle; fill it nearly but not quite full of water; having previously ready a cork that will fit it. Pour in the quantity of strong vitriolic (sulphuric) acid, that you know from previous experiment will barely neutralize that quantity of saline matter. Cork the bottle, and tie down the cork instantly. The carbonic acid gas will thus be combined with a solution of glauber's and epsom salts, which may be kept in a cool place. In the same manner the dose may be altered or diminished, or sulphat of iron in the proportion of 3 or 4 grains may be added if the symptoms of the patient require it, and a mineral water produced more efficacious than any that nature presents to us. T. C.

LETTER FIRST, TO THE EDITOR.

QUÆDAM DE VINO. ON WINE.

Ecclesiasticus ch. xxxi. v. 27, 28, 29. "Wine is good as life "to a man if it be drank moderately: what is life then to a man "that is without wine? for it was made to make man glad. Wine "measurably drank, and in season, bringeth gladness of the heart, "and cheerfulness of the mind; but drunken with excess, maketh "bitterness of the mind, with brawling and quarrelling."

I could produce many parallel passages to the above, from books of still higher authority than the wisdom of the son of Sirach. The history of Noah, the fable of Abimelech, the marriage of Cana, the disputation in Esdras, &c. are all authorities to shew, that the moderate use of wine, even for convivial purposes, has received the highest sanction that authority can give it; and they shew too, that we are not called upon to renounce the gratifications of appetite, when they can be enjoyed with prudent restraint, and without injury to ourselves or to others.

Having then presented you, my friend, with some preliminary observations that bear upon the science of good eating, permit me to offer you some remarks that lead to the science of good drinking: for like Castor and Pollux they are strongly allied to each other, and when the dishes set, the decanters rise.

I shall not dwell upon the wines of the ancients, the Falernian, the Formian, the Cæcuban, the Massican, the Calenum, the Aulicum, the Lycean, the Chian, the Egyptian (Marœoticum) the Sabinum—for we know too little about them except that they were generally estimated somewhat in the order here mentioned as we find from Horace's *vile potabis modicis Sabinum cantharis*, and some other odes. Some wine has been found at Herculaneum and Pompeii, but not enough in quantity, or in a state to judge of its quality.

In fact, the ancients knew little on the subject; they had no system that I can find of keeping their wine: they had no glass bottles, their wine was kept, in casks, in jars, or in leather bottles.*

I do not precisely know without more search than the subject is worth, what were the distinctions between the *Testa*, the *Cadus*, the *Lagena*, the *Amphora*, in which they kept their wine: or between the *Ampulla*, the *Urceus*, the *Cantharus*, the *Diota*, the *Ciborea*,

* This explains the scripture passage, "For what man putteth new wine into old bottles?" Their new wine being apt to ferment.

(Squash or Gourd?) which seem to be the demijohns filled for a drinking bout; or the *Pocula*, the *Cyathi*, the *Vitrea*, the *Chrystallina*, the *Murrinæ*, out of which they drank; and of which, the Cyathi were of the smallest size, as I think in opposition to Dr. Adams; the Vitrea and the Chrystallina being of late date.

They had, as all well regulated communities ought to have, some repository for the sovereign power, a *Symposiarch*, *Archipoesia*, *Arbiter bibendi*, or toast master, chosen by the throw of a die; the successful throw, being supposed to be regulated by Venus (*Quem Venus arbitrem dicit bibendi*): for the ancients also, were "won' to entwine, the myrtle of Venus with Bacchus's vine." Sometimes they adopted the silly practice of drinking a Cyathus* for each letter of their mistresses' name: *Nævia sex Cyathis, septem Justina bibatur.* I do not recollect any other specimen of their toasts, excepting the girls they were enamoured of.

Vultis severi me quoque sumere
Partem Falerni? Dicat Opuntiæ
Frater Megillæ, quo beatus
Vulnere, qua pereat Sagitta.

Mankind however, were much addicted to getting drunk, as we find in every part of history from Noah to Holofernes, from Alexander the Great to the tippling philosophers of Lucian's supper; without the hospitable excuse of Horace, *Recepto dulce mihi furere est Amico.*† They complained grievously of the effects of drinking. *Quo me Bacche rapis tui plenum? Evoe, Evoe, parce pater!* and so forth. These are symptoms of acid wine and head-ache. They probably knew not how to regulate the fermentation; they had no brandy to mix with their wines, to counteract the tendency to acidity: they drank their wines too new; for Horace seems to consider the four years old wine as a treat, *Deprome Quadrimum.* Nor were their wines clear, nor had they any cocks or spigots.

* This would be hard work, if, as Dr. Adams [Rom. Antiq.] supposes, the Cyathus held a quart.

† Expressed with much greater spirit in that fine old song "Welcome to Paxton, Robin Adair."

I will drink wine with you Robin Adair,
I will drink wine with you Robin Adair:
Rum-punch, ay, and brandy too:
By my soul, I'll get drunk with you—
Why did'nt they come with you
Robin Adair?

But enough of the ancients; let us follow Horace's model of a good epic poet, *In medias res semper festinat:* shew me at once the way to your cellar; if it be not as well furnished as Mr. Paymaster Rigby's or old Q's,* we will suppose it to be so.
What is this? Malmsey: good.

"Come broach me a bottle of rich Malvoisie,†
"Tis the boast of the Marmion tavern."

But this, like the Constantia, (the cape wine), Tokay, &c. is good only as a cordial or to give flavour to other wines, particularly the north side Madeira. It does not equally improve the south side wine. I think it is better kept in bottles than in casks.

When a wine is kept in a cask, three things are to be considered: what is the wine: what is the cask: where is it kept?

The effect produced by age on cask wine is this: the cask is porous, and there is a constant and gradual, though slow evaporation from the wine through the pores of the cask: the strong rich wines become concentrated, mellowed and improved in all respects; except that, if the wine be remarkable for any fine or peculiar flavour, that flavour will gradually be weakened, though the fullness, richness, and mellowness of the wine, will be improved. Hence, Tokay, Cape wine, Malmsey, the padre Ximenes, and Pachioretti Sherry, and the first qualities of Calcavella, are best in bottles after they have remained four or five years in the cask. These are the cordial wines; the wines to drink a glass of, after the course of sweet-meats, bon-bons, &c. and are certainly finer cordials than Noyau, Mascarille, Eau de Garuce and that class of spirituous impregnations.

Another consideration is, what is your cask? New oak gives an astringency to wine, in consequence of the gallic acid and the tannin of the wood being dissolved, which to me is extremely disagreeable except in port wine: and even that is better without it. New oak, is excellent for new rum and new gin; because

* The duke of Queensbury, lately deceased.

† Malvoisie. This is a name given to three different kinds of wine. 1st, It is the wine of Malvasia, the ancient Epidaurus; but better made in the island of Candia. 2dly, It is a Muscat wine from a grape grown in Provence. 3dly, It is the Malmsey of the island of Madeira. Malvasy, Malvisy, Malmsey, are names synonimous. There is a French Muscat grape also, called Malvoisie, a table fruit, of which wine is not usually made. It is not uncommon in the hot-house vineries of England. The Malmsey-Madeira, is the wine to which the name of Malmsey ought to be confined.

these liquors frequently contain a deleterious acetite of lead, which the gallic acid throws down; and this may also be the case where leaden worms are used in the distillation of brandy, particularly Spanish brandy; but for wine, most certainly old casks in sound, are greatly preferable.

Where do you keep your casks? The cellar is good, for wines that are not required to be full and luscious. Almost all the French and German wines, will sour in a warm temperature. A cellar uniformly about 50° of Fahrenheit is the best situation for them. Port wine requires a temperature of about 60 degrees. In England the best wine merchants keep a stove in their cellars. But Burgundy, Claret, Champagne, Vin de Grave, Vin de Chablais, Rhenish or Moselle, would be apt to turn sour in a warm place, especially if the warmth was not steady. Hermitage, Burgundy, Claret, Port, Florence, Sicily wines, lose colour, and flavour too, in casks, if they be exposed to alternations of heat and cold. Thin-bodied wines cannot bear it. There is not saccharine matter and mucilage enough to retain the strength and flavour: the body of the wine itself evaporates.

Madeira, Sherry, White Port, Lisbon, Malaga are improved by warmth: they bear also exposure to alternations of weather; by gradual evaporation they become stronger, richer, mellower; and a garret is better for them than a cellar.

In nine years, a pipe of Port wine kept in a cellar averaging from 42 to 50° of Fahrenheit, had lost the Port wine flavour, was of the colour of Madeira, and had diminished by evaporation exactly nine gallons: but was not in any degree sour. Madeira in a garret, I fancy would lose in rather a greater proportion; but less than Lisbon. For the richness and fullness of the wine, impedes but does not prevent evaporation. Casks so exposed to the warmth of summer weather, should be frequently examined. A good substitute for the common cock is a desideratum. The brass cock, is apt to collect verdigrease: the cedar spigot and faucet, must be long boiled, and soaked in brandy before it can be trusted: the spigot and faucet bushed with white metal, is bad; the metal is acted on by the acid of the wine: the quill is too slow. The persons who grind glass stoppers for experiments on air, could easily make a glass cock, or spigot and faucet. The iron hoops of a wine cask should be painted.

The best fining for wine of any kind is half a pint of *skim-*

med milk, beat up with the white of one egg, and then gradually with a pint of the wine, for a quarter cask.

No wine should be bottled, till it has been fined, and till it has remained four or five years in the cask. If the high flavoured red wines stay longer in the cask, they lose colour and flavour. The change the wine undergoes in the bottle (called sickness, which continues in newly bottled port wine from four to six months according to the fullness of the bottle) depends, if the bottle be well corked, on the space between the cork and the wine; for this is all the air the wine has to act upon. If the bottle be filled nearly up to the cork, little change will be made in the wine: hence if wine be bottled, that space ought to be left greater in new than in old wine. By thus acting upon the included air, a gradual mellowing of the wine takes place, and the tartar with a small quantity of the colouring matter subsides. In red wines, the peculiar flavour is contained chiefly in the colouring matter, which exposure to cold precipitates: that colouring matter, depends usually, not always, on the skin of the grape.

No cork should be used, till its soundness be examined; till it be well boiled in clean water; it should be driven by a machine under the direction of a man who is by trade a bottler of liquors; the bottle should be placed on its side. Never bottle your own wine or leave it to your servants, if you can help it. Remember, they who make it their business to do any thing, do it better than others who have but occasional practice.

Having thus made en passant, some general, and I hope useful observations, I return to Malmsey, which the French (who have no wine so good) call Malvoisie.

It is too rich to drink alone. From one twentieth part to one tenth part of old Malmsey, very greatly improves the common Madeira wine. The vino tihnto, a coloured wine, a Tent wine of Madeira, is *I believe*, a species of Malmsey not old enough to have yet lost its colour. I consider this as the old sacramental wine of the church of England.

Common Madeira may be greatly improved, and is so when wanted for immediate drinking, by a small quantity, (a desert spoonful to a bottle) of well clarified syrup of the finest loaf sugar. I believe in addition to this, it is not unusual to put a teaspoonful of a filtered vinous solution of isinglass in good Madeira. These give a fullness, a richness, and a silkiness to the wine, that to my palate is very grateful. But the isinglass is apt to precipitate on standing and exposure to the air.

Your next cask is *Madeira*. Is it London particular? Is it bill wine or barter wine? Is it Cercial? From the north, or the south side of the island? The London particular, is the highest priced wine for the London market: next to that is the bill wine, sold for bills of exchange: next to that is the barter wine, exchanged for goods. The wine of the south side of the island, as the Cercial wine, is much the richest: the northern side is comparatively harsh. Wine is made up in Madeira, by mixing, 1st, a certain quantity of old with new wine: 2d, a certain quantity of Malmsey with the common wine: 3dly, a certain quantity of north side with south side wine. The more old the more Malmsey, the more south side wine, the better and dearer is the mixture. Clarified syrup is a frequent substitute for Malmsey. Teneriffe is, I believe, lately, introduced as an adulteration.

All wines are vinegars as you say. But the older, the fuller, the richer the wine, the more wholesome is it, and the less apt to produce indigestion, heart-burn, and of course gout.

Madeira should not be bottled: frequently the ullage is the best part of it. Madeira is adulterated, by Teneriffe, by Sherry, by Lisbon, by Malaga, by Fayal. Sherry hurts the quality of the wine least, but the Sherry flavour cannot be disguised. Teneriffe spoils it in flavour, and in body. The twang of common Lisbon is detestable; so is Malaga unless very old and very dry. Fayal does not deteriorate the flavour, but it renders the wine meagre.

The harsh, subacid Madeira commonly met with, is extremely unwholesome. A good judge, will prefer the smooth, full, silky wine; though I confess this is a sensation frequently given as I have said before, by a slight admixture of clarified sugar. It approaches however nearest to the full rich south side wine; and is less apt to disorder the stomach.

The clarified sugar, should be of the best double refined, dissolved in clear pure water, boiled with the white of egg, and filtered through a flannel jelly bag. The isinglass addition, I suspect only, from my own observations and experiments, but I think I have detected it. A solution of terra japonica, will always throw down isinglass or any other animal gelatine.

You have *Teneriffe* there. Very old Teneriffe is drinkable. I have tasted none good for a sitting. Common Teneriffe ought not to find admittance, unless in the vaults of a professed wine merchant. If not the *Vile Sabinum*, a common homemade wine, it is not much better.

Marsala. A strong full bodied wine; heady; devoid of flavour. It is from the Madeira grape planted in Sicily, which has degenerated. While at Madeira the Rhine grape is so improved as to produce the Cercial. Malmsey in small proportion with Marsala and north side Madeira makes a good wine.

Sherry. The sack of Shakespeare's time, was, a mountain wine brought into the town in skins, *sacs*: whence the name "mountain," commonly used in England for Malaga. Sack was either the sac wine of Xeres, or of Malaga; the former was the Sherris-sack, the latter the Malaga-sack. 2nd. part of Hen. 4, act 4th. Sir John Falstaff says,

"A good Sherris-sack hath a two-fold operation in it; it ascends me into the brain, dries me there all the dull, foolish and crudy vapours which environ it; makes it apprehensive, quick, forgetive, full of nimble, fiery and delectable shapes, which being delivered over to the voice, the tongue which is the birth, becomes excellent wit. The second property of your excellent Sherris, is, the warming of the blood, which before, cold and settled, left the liver white and pale, which is the badge of pusillanimity and cowardice; but the Sherris warms it, and makes it course from the inwards to the parts extreme; it illuminateth the face, which as a beacon gives warning to all the rest of this little kingdom, man, to arm; and then the vital commoners, and inland petty spirits, muster one and all to their captain the heart, who great and pufft up with this retinue, doth any deed of courage; and this valour comes of Sherris. So that skill in the weapon is nothing without Sack; for that sets it a-work; and learning a mere hoard of gold kept by a devil, till Sack commences it, and sets it in act and use. Hereof comes it that prince Henry is valiant; for the cold blood he did naturally inherit of his father, hath like lean, steril, and bare land, manured and husbanded and tilled with excellent endeavour of drinking good, and good store of fertile Sherris, that he is become very hot and valiant. If I had a thousand sons, the first human principle I would teach them, should be to forswear their potations and to addict themselves to Sack."

Hence it appears that Sack, is the genuine name; and that Sherris Sack, Sherry or Xeres (Yery) is one (and the best) kind of Sack. Doubtless it is so: the Padre Ximenes (Yemanes) and the Pachioretti Sherry, often to be found in the London market, are fully equal to Malmsey Madeira: but no one can tell what good Sherry is, from the wine so called, usually imported in this coun-

try. Sherry will bear warmth, and gradual concentration equal to Madeira. But the first quality of it should be bottled in due time to preserve the flavour, which in fine Sherry is well worth preserving.

Colmenar, is a cheap sound wine, but the flavour is very inferior.

Lisbon: white Port. If these wines be kept till they are old and dry, they are tolerably good: but once for all, a judge of wine, and a judge of its effect upon the health, will confine his drinking chiefly to Madeira and Sherry of good age. These in moderate quantities, (and I should consider a pint daily and habitually, as beyond the scale of moderation) will probably do good. Other wines may be taken occasionally; but all others are in my opinion decidedly inferior. Dr. Nesbit was right when he translated Falernum by Madeira.

The *Calcavalla* Lisbon, is the highest and best flavoured wine of the kind; but not fit for a beverage to sit down to.

All this remark you know would be useless at a French table, where a bottle of meagre Bourdeaux is set before the guests, and once, or at the utmost twice, during the continuance of a two hours' dinner, a glass of the finest Bourdeaux, of Constantia, or Malvoisie is sent round: the desert finishes with Noyau, Mascarille or some of the Martinique liqueurs, and the guests adjourn to coffee. But in England, and with us, it is of great importance to know what kind of wine we can sit down to for an hour, with most pleasure to the palate, and least ill effect upon the health; remember Plutarch's advice, *ei oinos esti kakos eis numphas kataphugein:* if the wine be bad, fly to the tea table, as Dubois in his "old Nick," well translates it.

Is your cellar supplied with French wines? For a well appointed cellar cannot be without them. Your Hermitage, your Bourdeaux, and Sauterne; your Vin de Grave and Chablais, you import in casks: your Burgundy and Champaigne in bottles.

Vin de Grave, of the first quality I have never seen here: it is a well flavoured, rich, gold-coloured wine, worth attention; but the inferior qualities are not worth importing: nor in my opinion is Chablais.

Hermitage. This is the fullest bodied red wine that France produces. It is a sound good wine, of high flavour. It is particularly useful to give body to and develope the flavour of claret (Bourdeaux,) and a small quantity greatly improves Port. But it

is well worth drinking alone; and when bottled at a proper age, is a fine wine; equal if not superior to the best red Port.

Bourdeaux wine: Claret. This last is the English name: the French call it Bourdeaux wine. Thirty years ago, when what would be called passable Claret was bought at Bourdeaux for 800 livres the Barique, the London purchasers gave 2500 livres. The best qualities of Claret, are La Fitte, Chateau-margo, St. Emilien and St. Julien, vineyards within the district of Medoc, near Bourdeaux.

Good Claret, (seldom imported here) is a fine wine. It is among the best wines to sit down to, as a bottle of it may be drank without intoxication, and the odour and the flavour of the finest kinds, are both extremely agreeable. But even good Claret will bring on a fit of the gout, with persons liable to that disorder sooner than almost any other wine. The better the wine, the less apt is it to produce this effect.

For the continental market, Claret is mixed with juice of fresh violets and hermitage: for the English market, Brandy is added to it; and the wine is the better for the addition.

Young men, that is, men on the right side of forty, may drink Claret with impunity, if they attend to moderation, and have no disposition to gout or stone. Otherwise, they had better keep close to Madeira and Sherry.

Claret should be kept in a cellar, on the side; in the temperature of about 50°. The flavour, will gradually dissipate from the cask, and too much warmth, will be apt to sour the wine.

Burgundy. I consider this when good, which is a rare quality here, as the best of the French wines. It is of good body, but extremely delicate and hard to be kept. The flavour is higher than either Hermitage or Claret. I have kept it in bottles three years in wet sand in a good cellar of temperature 55°. For want of care in bringing it over here—from the corks being permitted to grow dry—and probably also from the inferiority of the wine imported, it is generally "pricked," or with a tendency to acid decomposition, in which state, it is not easy to find a more unwholesome beverage.

Champagne. This is either tinted (*oeil de perdrix*) or colourless: either *mousseux* sparkling, or *non mousseux*, still Champain. It is a thin wine of delicate flavour. The sparkling Champain, is made so, by closing it up in very strong tight casks, before the fermentation is fully over. In this state, it is made to

combine with much carbonic acid gas; which makes it act quicker on the stomach, and renders it sooner intoxicating. It is a pleasant wine occasionally, but meagre, and one that quickly palls upon the appetite. It is far inferior to Hermitage, Burgundy, or Claret, and not greatly superior to good English Perry. Half Sauterne, and half Seltzer water, is a beverage nearly as good as Champain.

Sauterne. A wine of delicate flavour, little if at all inferior to the Champagne non mousseux. Considering its quality, it is the cheapest of the French wines imported here; and if like all the rest of the French wines, it did not produce tendencies to gout and stone, it would be a very desirable table wine. But there is no French wine that is not bad for persons who have tendencies to gout.

Chablais. Tired of Champagne and Claret, this wine of moderate flavour and moderate strength, became preferable to me as a regular beverage to the others. But it has no merits that should induce its importation. It is superior to Fayal.

The common *Rhine wine*, and *Moselle wine*, are little superior to good cyder. I have drank repeatedly Hock of 1726, and Hock of 1749, which being kept in large quantities, had not become vinegar: it was comparatively to the common Rhine wine, an excellent liquor. But Hock is gouty: it produces stone and gravel, it is perceptibly an acid wine, and fit only, to drink after rich soup to clear the mouth; for which purpose only it is usally introduced in England, in glasses fantastically imitating the course green tinge of the German wine-glass. Punch after strong soup is quite as good. Common Hock is not much better than strong cyder.

Of the Italian wines, we import none, I believe except those of Sicily: the red wines of that country are cheap, and for their price very good. Certainly superior to the common clarets. So is Florence. The *Lachryma Christi* and *Cota-roti*, we know little of here.

Port. Vin d'Oporto. Sir Paul Methuen, and the woollen manufacturers of Leeds and Halifax, have been the chief causes why Port has become the national wine of the English. It has arisen from the shopkeeping notions of the British statesmen, and the persevering representations or rather misrepresentations of the manufacturing interest. To mercantile monopoly, and to manufacturing monopoly, all the great interests of that nation have hitherto been made to bend.

All the first Port wine is regularly bought up for the London market, where there is sale for a much larger quantity than Portugal produces. It is made up in Portugal with brandy, but I do not know of any other admixture. Hermitage improves it. Few wines admit of so much difference in quality; nor is the Port wine imported into this country, to be compared to the English Port. There may be occasional exceptions, but there are very few. The price of Port wine, has gradually risen in England, within thirty years, from 26l, sterling the pipe, to 100l.

In that country, where the management of it is well understood, a pipe of Port, is fined with whites of egg, within a short time after it is deposited in the cellar. It stays there from 4 to 6 years. The cellars in England are all arched with brick; the bricks are *grouted*, that is fresh mortar in a thin paste is poured into all the joints so as to fill up every interstice; a process in my opinion indispensible to every arch of brick or stone. The arch is then covered with a coating a foot thick of clay well beaten with beaters. It is thus rendered impervious to moisture. If the cellar walls are not perfectly dry they are cased with rough boards. Brick partitions at right angles with the wall, are built so as to divide each side of the cellar into bins, calculated each to hold a pipe of wine in bottles, or about 50 dozen of 14 to the dozen. The partition walls extend from the cellar walls about four feet, or a convenient distance for a man to reach from the front to the back part of the bin. The front ends of the partition walls are finished with upright square posts, grooved for boards to slide in, which form the front of the bin. Frequently the front is of brick, and a lid with a padlock secures the whole bin from the depredation of servants. The wine is placed on dry saw dust on its side. It is never touched till about nine months after it has been bottled. Care is taken to exclude currents of air; so that the temperature shall be kept as nearly equal throughout the year as possible. The bottles when wanted are carefully brought up in a basket long enough to hold two bottles endwise, on their side, the crusted side downwards, undisturbed. The corks are drawn while the bottles are still kept in a state of inclination, not upright. The cork screw should be the compound double patent screw, that draws the cork without pulling and tugging, or any other effort than that of turning the screw itself. The cork being drawn, a silver anti-guggler is inserted, so as to admit the

external air to the bubble of air included at the upper side of the bottle; the wine is thus decantered without the sediment being disturbed by the conflict of the wine going out, and the air coming in. The wine is strained into a decanter through a silver strainer to which fine muslin is fitted, and is drawn off no nearer than to leave a glassful *at least* in the bottle.

The wine in winter time, is then set before the fire, and in summer time it is never cooled. Cooling Port or Claret, makes it muddy, and totally destroys the flavour. A good judge of wine, and who knows how to enjoy it, will never cool fine, high flavoured wine of *any* kind below 50° of Fahrenheit: in summer time in this country, the sensation of coolness, is pleasanter than the sensation produced upon the palate by middling wine. But it is a vile and a vulgar practice, to destroy the flavour of fine wine by cooling it down to 33 or 34° by means of ice, even should the thermometer be at 96°. Destroy the taste of *bad* wine, by ice, if you please; but a man who does so by *fine Madeira*, does not deserve it.

At an English table even of fashion, the every-day wines, are either Sherry or Madeira at dinner, and Port or Claret afterward. In summer, both. Lachryma Christi, Cota-roti, Hermitage, Burgundy, Champain are the wines of ceremony only.

But the English seldom prefer Claret to Port: the Irish seldom prefer Port to Claret. The English drink no liqueurs: Muscadel and Frontiniac, are sometimes produced to the ladies as sweet-meat wines; but not generally.

The precautions in keeping wine that I have enumerated, are not exclusively confined to high fashion or great wealth: every English gentleman of tolerable fortune attends to them as indispensible. Our different practice in this country, has arisen from necessity. Our immediate ancestors could not afford the trouble or the expense, nor had they the taste to require, the careful bottling, corking, and keeping of wine: but with respect to Madeira, their accidental practice has been in all respects an improvement. An Englishman does not understand Madeira; which after all is *the* wine, the *Falernum* of the moderns. Nor does an Englishman understand the practice of smoking, except in the lowest beer-houses. I acknowledge a segar is frequently a luxury: so to a sailor is a quid of tobacco; but the one indulgence and the other, are so inconsistent with neatness and cleanliness, that in decent society they ought to be renounced. I hope the time will never again arrive, when it shall be necessary to admonish the

beaus of Philadelphia, that segars are not admissible in the ball room on Washington's birth day.

Thus managed and thus drank, Port is a very fine wine; and satiates far less than any other red wine; but after all, it is not Madeira.

The Southampton and Guernsey Port, (that is, the Port generally sold there, and frequently smuggled there) is a thin kind of wine, pleasant but without body, and without merit.

When wine is drank, the glass for red and the glass for white wine should not only be different, but of different forms. A full small glass of wine, is not half so agreeable, as the same quantity out of a larger glass. There is an association of gluttony, and vulgarity, and slovenliness in a full glass. Bumpers should be banished to bacchanalian parties, which are never epicurean. The stem of the glass, should be long enough easily to admit two fingers without touching, and soiling the bulb. The glass should not only be the finest flint, clear, without colour, blebs, or blemishes, but thin. Half a glass of wine (and more should seldom be filled) has more odour and flavour, in a tolerably sized glass, than the same quantity in the form of a bumper. All ornaments about a wine glass, are inelegant, bourgeoise; they savour too much of finery. The character of a gentleman's establishment, is *simplex munditiis*. The only use of a cut border to a drinking glass, is as a memento, not to fill it beyond the lower edge of the ornamented border.

Hence, also, napkins at dinner, and doyleys after, are necessaries: not so, water glasses. The use of them like the four-pronged silver forks, arises from an affected imitation of foreign customs: after a French dinner, where the fingers perform much of the duties of a knife and fork, water glasses are necessary: but not after an English dinner at a genteel table; where meat is seldom touched with the fingers: where the dishes are solid for the most part, and the meat is cut, not torn: where the right hand is occupied by the knife and the left hand by the fork: while at a French dinner, the right hand holds the silver fork, and the left hand a piece of bread, while the knife is deposited in the pocket, being comparatively little used. Not to mention the associations of uncleanliness and indelicacy connected with the use of water glasses. Where the dinner is a mixture of French and English cookery, the silver forks are not out of place.

If possible, the room to drink wine in, should not be the dining room: and a glass or two of rose water sprinkled upon the carpet, is a cheap luxury.

Thus have I extended perhaps to an unconscionable length, my remarks on wines. I have confined myself to the wines usually imported. Of homemade wines, I shall present you with my experience hereafter.

I have in the beginning taken the licentia poetica, (or if you will forensica) that is, the licentia fingendi, and supposed your cellars filled with choice liquors instead of choice books. I wish you had more abundance of the first, and more room for the last. I know you are amateur of good living in all the *good* senses of the word: nor should I greatly object to apply to you, Akenside's picture of the Teian Bard.

I see Anacreon smile and sing,
His silver tresses breathe perfume,
His cheeks display a second spring
Of roses, taught by wine to bloom.
Away deceitful cares away!
And let me listen to his lay.

Adieu my friend.

EPICURI DE GREGE PORCUS.

LETTER SECOND, TO THE EDITOR.

QUÆDAM DE VINO. ON WINE.

[I insert this letter, which was intended for the 4th number, in the present, because I am prejudiced in favour of bringing together, as much as possible, all the communications on one subject. T. C.]

My Good Friend,

I promised you some information on homemade wine; the *vile Sabinum*. Of the many English and American receipts for these liquors, there are none worth a cent. Nor is the practice, in this respect, of even Mr. Cooper of New Jersey, entitled to more approbation. I shall in this essay tell you, not what I have read, but what I know, partly from my own experience, and partly from the experience of those on whom I can depend.

Wines may be made out of apples, pears, quinces, cherries, currants, gooseberries, blackberries. Out of the fox grape, the natural small white grape, the small round black grape. Out of the imported Sweet water, Claret and Burgundy, and Rhine grape. Wine can be made out of the Malaga raisin.

In the southern states, it can be made out of the Constantia, and out of the grape produced by sowing the common jar raisin. But it has not been so made as yet.

Cyder. The method of making cyder is sufficiently known in this country among those who make it a business to sell it in the seaport towns. The richest cyder I ever tasted, had a gallon of good apple brandy, put to a quarter cask at the commencement of fermentation: it was made out of high flavoured apples.

The common cyder-royal, cyder and honey, and cyder-wine, made by boiling the juice of the apples, are very bad. Cyder is made more vinous, by pouring boiling water on Malaga raisins, steeping them for about thirty hours, and putting the pressed juice of about half a bushel to the quarter cask of apple juice, previous to fermentation, with about half a gallon of brandy. This is cyder-wine and worth attention. The goodness of cyder greatly depends upon racking it. The casks should be previously sulphured and rinced out with brandy.

Perry, is made like cyder. I have tasted none good in this country. Our friend, Mr. P. at your persuasion, had two quarter casks of Perry made of the juice of the common egg pear, but it was thin and meagre. The Perry of England, is little, if at all, inferior to Champain: and very superior to common cyder.

Quinces. I have not tasted this wine. A good judge informs me, that there are very few wines of any description equal to it in body and flavour. Doubtless a small proportion of quinces would greatly improve cyder.

Cherries. In Philadelphia, the wine of the morella cherry, coloured, is sold often as red Port. I suspect it is too harsh to be wholesome or palatable.

Currants. All homemade currant wine is made too sweet. To one gallon of the pure juice of Currants, add one gallon of water. To each gallon of the mixt liquor put 2½lbs. of the best clean Muscavado sugar: ferment with half a pint of yeast, in a cool cellar, from 20 to 30 hours, or till the fermentation is over, and the head begins to fall; filling up the cask from time to time as the liquor works out of the bung-hole. It may be known to have suffi-

ciently fermented, when the head of yeast at the bunghole begins to subside. Add to the quarter cask two gallons of good brandy, or half a pint to each gallon of wine. Let it remain bunged up for four months; then fine it with the white of an egg beat up in skimmed milk. In a twelvemonth rack it off in a clean cask, rinced out with a little brandy and water. This wine, to be *good*, ought to remain in the cask at least four years after racking. 1 cwt. or 112lbs. of fine ripe currants, will yield near 10 gallons of juice. Six pounds of sugar will add half a gallon to the bulk of the liquor. A mixture of about one sixth black currants, greatly improves the flavour. For smaller quantities proceed thus:

Take equal parts of currant juice well strained through linen or flannel, and water. To 10 gallons of the mixt liquor add 25lb. Muscavado sugar, previously dissolved in the water. Add about a gill of yeast; let it ferment in a cool place about 24 hours, or till the fermentation is over. Beat up the white of an egg in a quarter of a pint of skimmed milk. Stir it about well. Bung it up: in four months rack it off, and add a quart or three pints of brandy.

The wine from Gooseberries. Dr. Clark is right, in his Travels to Russia, when he says, this is equal to any Champain. But gooseberries do not grow so well in America as they do in England. Gooseberry wine made sweet, and flavoured with the blossoms of elder flowers, is not a bad imitation of Frontiniac.

Blackberries. I do not know any thing of this wine; I have tasted the wine made from

Elder Berries; but it has no qualities to recommend it.

All the writers on made wines, strongly exclaim against brandy being put into them: this is from a silly and affected regard for health and sobriety: *all wines* are the better for it. When Port wine, or any of the thin wines are in danger of becoming acid, there is no better remedy for the evil than half a gallon or a gallon of good brandy to the quarter cask. *Experto crede Roberto.* We hear a great deal of exclamation amongst physicians, against the deleterious effects of fermented liquors, particularly of ardent spirits. They might as well talk of the deleterious effects of arsenic or opium. They are all poison *in excess;* they are excellent and invaluable remedies in moderate doses. If a man drinks to excess, it is a gradual poison, greatly inimical to muscular strength, and also to mental vigour; and so it is if he eat to excess; but in moderation, wine greatly aids both the one and the other; independent of the pleasurable zest it gives, even to the

best society. I do not find that water drinkers live longer, or are more free from maladies, than those who enjoy their wine in moderation; and I am well persuaded, that the latter class do not, in general, exceed so much in the article of eating.* For a labouring man, beer may be better than ardent spirits; but bishop Warburton was right when he said, "they who drink beer will think beer." For my own part, I confess, I entertain something of the common prejudices against obstinate sobriety, and I fully accord with Sheridan's song.

Truth they say lies in a well:
This I vow I ne'er could see:
Let the water drinkers tell,
There it always lay for me.
But when sparkling wine went round,
Never saw I falsehood's mask,
But still honest truth I found,
At the bottom of each flask.

The Fox Grape. The pure juice of the ripe fox grape to my own certain knowledge, makes a full bodied, strong, well flavoured Madeira-coloured wine, which in my opinion, if these grapes were cultivated, would fully equal the best Madeira. Some juice was expressed out of the fox grape, by part of my own family; it was strained; it was put by in a decanter: it was left with the stopper out, exposed to the frost out of doors through the winter. It was put by with the stopper out, in a sideboard till July 2; of the year 1802. There was a mother on top of the wine in the decanter. It was somewhat hard, but well flavoured, full bodied, strong, and equal to good Madeira. I drank some wine of the fox grape afterwards made at Havre de Grace. I suspect it was not the pure juice; it was a tolerable wine but thin. The fox grape, is in its growth, in the pulpiness of its fruit, and in many of its habits much like the Constantia grown in Pennsylvania. I am well satisfied it is worth careful cultivation for wine. No imported grape is to be compared with it for this purpose.

The small round white and red wild grape. I know nothing of the wine from these. If treated as apples are for cyder, I make no

* Dr. Darwin, who left off wine when the gout compelled him, used to indulge afterward in eating, and would swallow, without remorse, his bowls of rich cream, while he would inveigh against the smallest portion of fermented liquor.

doubt they would make a good wine. Let it be remembered, that the more juicy, and the more pleasant a grape is for the table, the worse it is for wine. Such grapes make thin, meagre, acid wines, in all the instances I have known.

The imported, Sweetwater, Claret and Burgundy and Rhine grapes. All these are too juicy to make wine of. They require sugar and brandy. The wine made at Mr. Henderson's at Huntingdon, the wine made at Harmony, near Pittsburgh, the wine made by the Swiss settlers near St. Genevieve, has all the same fault. It is too meagre: it wants body; sugar and brandy would greatly improve it. The Harmony wine, if made Mousseux, would not be inferior to Champain. Even in Champagne, they are frequently obliged to add both sugar and brandy; and the wine we so greatly prize, owes its goodness to materials as easy to be procured here, as they are in Champagne.

Constantia. The Constantia grape grows in Pennsylvania, but for want of sun it is pulpy, not juicy, and it ripens late. I am fully persuaded, that this grape and the fox grape (equally good) are the stock-fruit for wine in this country. I earnestly recommend them to the States south of this.

I close these remarks by stating my full conviction that *good* wine can be afforded in America, cheaper than good cyder; can be made to greater profit, and in greater plenty.

Malaga Grape. Two thirds of all the white wines sold at the inns and taverns of England, the Madeira, Sherry, Calcavella, Lisbon, White Port, and Mountain, (as well as the White wine vinegar,) are manufactured at home out of the Malaga raisin. The present Harry Beaufoy, Esq, who succeeded to his father's vinegar-yard and wine manufactory, sold out his establishment for a life annuity of six thousand guineas a year.

I know not the processes for imitating each of these wines, but one essential part is, that the wealthy manufacturers of England can afford to keep their home-made wines, till age makes them really good.

It would be a manufactory well worth establishing in this country. The method of making White vine vinegar out of cyder and Malaga raisins you have given accurately in the port folio.

I have now presented you with my desultory remarks on wine; but I have somewhat more to say, better worth your readers' attention than any thing I have yet said on the subject.

I am an advocate for drinking wine, for the sake of good company, for the pleasure of drinking it, from motives of conviviality, and not merely as St. Paul recommends it, for the stomachs' sake. But I should not be an epicure, if I were not to insist on habitual moderation: this is the mark and the criterion of the *gentlemanly use* of every indulgence; nothing betrays vulgarity so much as excess. People who are not accustomed to good living, gormandize when they meet with it: those who are accustomed to it, have no temptation to exceed the bounds of moderate enjoyment. But I fear that my notions of moderation do not coincide with common practice. I am fully persuaded that wine as an habitual beverage much short of any thing like intoxication, lays almost the only foundation for the *gout* and *stone*, of the decline of life: these are one and the same disorder, so far as remote and proximate causes are concerned in producing them. I know of nothing that can excuse excess in drinking, but a typhus fever for which physicians prescribe it, or the intolerable pressure of recent misfortune, for which Horace, and after him Burns prescribes it on the authority of Solomon; *Dissipat Evius, curas edaces.*

"Give strong drink unto him that is ready to perish, and wine to those that be of heavy heart. Let him drink and forget his poverty, and remember his misery no more. Prov. xxxi. 6. 7."

Gie him strong drink until he wink,
Whae's sinking in despair;
And liquor guid to fire his bluid
Whae's prest wi' grief an care.
There let him bouse and deep carouse
Wi' bumpers flowing o'er,
Till he forgets his loves or debts,
And minds his griefs no more.

I was led into this train of reflection, by a passage in the Edinburgh Review for November, 1811, of which an account is given of some experiments of Mr. Brande on the quantity of alcohol contained in wine: I shall give the substance of those trials, with the obvious remarks of the reviewers, and add to them the experiments which I have seen you make on the same substances. The pleasures of the table consist so much in the circulation of the bottle, and the subject is of such great importance to health as well as to pleasure, that I can not think, this dissertation will be void of interest.

Alcohol is pure spirit of wine. M. Fabroni, an Italian chemist, being unable to detect alcohol in wine by any process previous to distillation, was of opinion that the alcohol procured from wine, was formed in it during distillation. Mr. Brande's experiments tend to an opposite conclusion; and seem to prove, that all the alcohol produced by distilling wine, existed as alcohol in the wine previous to distillation. On this point, I am careless who is wrong, and who is right, although I have no doubt that alcohol in beer is formed from the Fecula, and in grape-juice from the saccharine part, during fermentation.

But in the course of these experiments, made on upwards of fifty different kinds of foreign and home-made vinous liquors, of the very best and purest quality that could be procured, and according to all evidence, free from adulteration, Mr. Brande procured as follows:—

Of alcohol or pure spirit of wine

from Rum -	53, 68 per cent.
Brandy	53, 39———
Holland's Gin	51, 60
Marsala wine	17, 26 to 25, 87
Port wine	21, 40 to 25, 83
Sherry	18, 25 to 19, 83
Madeira wine	24, 42
Claret	12, 91 to 16, 32
Tokay	9, 88
Hock	8, 88
Raisin wine	25, 77
Currant wine	20, 55

From this table it appears, that Rum, Brandy and Hollands, consist of about half spirit of wine or alcohol, and half water. That Madeira, Port, Sherry and Marsala, consist of about one fourth spirit or alcohol, and the rest, the vinous liquor with which the spirit is combined. Hence it follows, that every man who drinks a bottle of Madeira or Marsala, drinks about a pint of strong brandy. Now, any man who beside his porter, or brandy and water at dinner, will sit down to drink in the course of two or three hours, an additional quantity of a pint of brandy mixt with a pint of water, would be regarded as very careless both of his health and his intellect, yet, this is the case with every man who swallows his bottle of any of these strong wines. That the digestion is injured, and that the mental capacity is injured, that

nervous irritation, and muscular debility are induced by excess in spiritous, liquors there can be no doubt; and whether this quantity be excess or not, may fairly be left to the unbiassed judgment of the reader.

The preceding remarks are sufficiently obvious to every body, but the following additional observations, I owe to yourself.

The liquid that the alcohol is combined with in wine, is not near so innocent as water: it is literally in the very best wines, Madeira for instance, *Vinegar*. Wine is vinegar, holding in solution, alcohol, sugar, mucilage, and vegetable gelatine.

Every man who drinks a bottle of prime London particular Madeira wine, drinks a bottle of vinegar mixt with brandy. It is the same with Sherry, Marsala, Teneriffe, Lisbon; with Port, Claret, Burgundy, and Champain. I have tried them all.

All wines are made from the fermented expressed juice of the grape: and so is all vinegar. The fermentation is pushed a little further in vinegar than in wine, but the difference is only more and less acid: time and access of air, destroys this difference altogether, and converts wine into vinegar.

Now for the proof of this.

For the purpose of ascertaining the minutest portion of acid in any liquor, the chemist relies implicitly on paper or cloth dipped in the juice of litmus, or in the juice of red cabbage. The lichen or moss from whence litmus is made, is infused in water to which a very small quantity of a solution of pearl-ash is added, just sufficient to make the tinge rather blue than red.

Or, water is added to the red part of the skin of the stalks of red cabbage, and a small quantity of solution of pearl-ash is added, just sufficient and no more, to produce a blue tinge. This blue tinge is discharged by all acids; and a red colour produced, that encreases in intensity according to the strength of the acid, of which it is made the test.

Upon a piece of muslin or white paper thus tinged blue, drop one drop of common vinegar; at some distance, drop one drop of good wine of any kind; then (at some distance) one drop of good cogniac brandy; then one drop of Spanish brandy; then one drop of peach or apple brandy; then one drop of good rye whisky. The vinegar will give the strongest red tinge—the wine, the next in depth of colour—then the spanish, apple, and peach brandies—then the cogniac will be still weaker—and the rye whisky if good,

will hardly tinge the paper at all. Neither pure spirit of wine, or pure water, will produce any change of colour.

If there be any acid in the brandies, it is owing to the vinous liquor from which they are produced being carried into fermentation, and driven over by careless management in the distillation, which is commonly the case especially in Spanish brandy: and is so sometimes in whisky; but not so often. This is an experiment that any of your readers may try, and satisfy himself of the truth of.

After this, are we to wonder at the Dispepsias and Cardialgias —at the indigestions, the acid eructations, the heart burns, the gout, the stone, &c. with which great wine drinkers are generally afflicted in the decline of life?

Your opinion is, and I acknowledge that every day's experience seems to corroborate it, that the constant and regular introduction of so much stimulating acid liquor into the stomach daily, tends to produce the *habit* of acid secretion throughout the system; a habit that may be propagated and become hereditary: and this is the cause of indigestion, gout, and stone; and not any morbid action merely of the solids, unless produced by, and producing this acid character, this morbid stimulus of the fluids. Nine tenths in number of all the human calculi, consist of acid deposition. Those who are afflicted with these symptoms, must persevere in the exercise of walking; they must decidedly leave off wine; they must avoid ascescent food; they must habitually take magnesia, or volatile tincture of guaicum, or alkaline liquors such as soda water; and sedulously keep up an active state of the bowels—they must confine their beverage to weak spirit and water; and of spirits, gin and whisky are the most unfashionable, but indubitably the most wholesome. By these means, the duration of a threatening fit will be lessened, and future attacks gradually prevented.

In England, Porter is, and is deservedly, a favorite beverage but that is *draught* porter. In this country, bottled porter is a favorite drink particularly in summer; I never tasted bottled porter or bottled ale, that did not approach to vinegar.

Of all wines old and strong Madeira is the best: next to that, the Padre Ximenes Sherry and the Pachioretti. Acid as all wines are, I do not think that half a pint of generous wine daily, even habitually taken, would be attended with any ill effects; for some counteraction to acidity is afforded, by the quantity of animal food we

indulge in: but I am very sure that no man can drink a pint of vinegar daily with impunity, whether it be mixed with alcohol or not. He will feel it in the course of years: the maladies of the decline of life, will furnish severe recollections of past imprudence. Years bring infirmities enough; we should be upon our guard not to add to them.

Adieu for the present. PINE TE KAI TERPEU *Vive, Bibe, Vale:* that is, eat, drink and be merry, but in moderation.

I hope it will be long 'ere our friends will have occasion to repeat over your grave, or mine,

Scripsisti satis; edisti satis; atque bibisti,
Nunc tempus abire tibi est.——

Yours'

EPICURI DE GREGE PORCUS.

TO CORRESPONDENTS.

I am so frequently asked why I do not give information on subjects that have not yet arrived in their turn, that I think it right once for all to state my plan. I shall conduct this work for a twelvemonth, and if I and my publishers find a common interest in the concern, until my plan be completed.

I have dwelt longer on the articles IRON and STEEL than I mean to do on the rest, because they are of so much importance, so little understood, and so little information of value has been collected concerning them.

The scattered papers of so many volumes which I have brought together, contain more instruction than any single treatise or any two treatises hitherto published, in any language; and the value will 'ere long be appreciated, by those who are willing to give attention, and who seek for information rather than amusement; and should the work stop here, I have no hesitation in saying that I have been of public service, on the most interesting and important of all manufacturies.

I propose in future numbers to take up about 100 pages of each number with the following subjects, upon all which my collections are prepared; the result for the most part of my own actual observation of manufacturing processes, or of communications from persons actually engaged in the manufactures; where that is not

the case, I can safely promise the best information that books can supply. I do not undertake to confine myself strictly to the series of the following arrangement, but I am not inclined greatly to vary from it.

History of *steam* engines: methods of consuming *smoke*.

Manufactures dependant on *copper:* assaying, smelting of Copper ores: alloys of Copper; Chrystals of Verdigrease; Verdigrease: Verditer: Green pigments prepared from copper.

Manufactures dependant on *Lead.* Assaying and smelting of Lead ores: massicot: litharge: red lead: white lead: sugar of lead: refining of Lead for silver: Milled lead for boxes: alloys of Lead: Shot.

Manufactures dependant on *Tin.* Tinned iron plates: tining of Copper: tinfoil: tinning of pins: Bronze: Putty.

Manufacturies dependant on *Gold*, *Silver*, and *Mercury:* various methods of gilding, silvering, and plating: assaying: parting: silvering of looking glasses. Alloys of these metals.

Manufacturies dependant on *Antimony* and *Bismuth.* Pewter: white metal: Types.

Colour making. Carmine: red lakes: yellow lakes: copper-brown: Lamp, Ivory, Frankfort blacks: pearl white, spanish white, flake white, white from Barytes and Strontian: saxon blue: nankeen dye: brown, dutch and rose pinks: sap green; Scheele's green, french green, brunswick green, olympian green (vid. copper:) aurum musivum: ultra marine: smult: bice: cinnabar: vermillion: chromat of lead and of mercury: patent mineral yellow: cheap paints: stencils; coloured chalks: pannels for painters: oil cakes: colour mills.

Chemical drugs in the large way. Pot and pearl ash: pure alkali: soda; ammonia: oil of vitriol: spirit of salt: aqua fortis: cream of tartar: radical vinegar: acids of tartar: of lemons: of sugar: of benzoin: sulphat of potash, of soda, of magnesia: calomel: corrosive sublimate: unguent. mercur: red precipitate: preparations of Antimony: of Bismuth: muriat of barytes: elastic gum tubes: purification of Camphor: the common quack medicines: method of detecting adulteration in medicines: memoir on chemical manufacturies with reference to the law of nuisance.

Tanning, with the modern proposed improvements. The processes for making Turkey, Morocco, and Russian Leather. Dying and staining Leather.

Bleaching, Wool, Silk, Cotton, Linen, Paper, Stained prints.

Dying, Wool, Silk and Cotton.

Printing Calicoes.

Pottery: glazing of pottery: enamel colours for pottery.

Glass Manufactory: With an abridged translation of Loysel, and Bos. D'Antic.

Manufacture of *Glue: Isinglass: Starch: Hair powder: Wafers: Sealing wax.*

Gunpowder and the purification of Salt petre.

Manufacture of *Alum:* of common *Salt.*

Varnishes, particularly the actual manufacture of Copal Varnish in the large way.

Etching on Copper and Glass: *Aqua tinta: Staining* of wood and bones: *Marble* polishing, &c.

The above with other articles of the same general description, will occupy the greater part of each number: about sixty pages more will be filled up with such miscellaneous matter as may occur to me from time to time.

Should the above plan be reasonably well executed and encouraged, this work will go on; if not, the end of the year will close it, so far as I am concerned. T. C.

I have received from a manufacturer of stone ware at Charleston on the Ohio, a specimen of what is deemed a very valuable and secret cement for joining together pieces of stone. I have tried it, and it is made thus. Melt 3 parts by weight of Rosin with one part by weight of wax; when fully incorporated add to them while fluid, one part by weight of finely sifted well-dried brick dust. A little more or less rosin makes the composition harder or softer.

Dr. Doddridge of the same place has sent me a very useful pamphlet on the management of Bees, with an improvement on the structure of the Bee house, the mode of colonizing bees, and taking the honey without destroying the insects. The directions seem to me judicious and practicable. It is printed at St. Clairsville on the Ohio.

END OF VOLUME FIRST—NEW SERIES.

Alexander & Phillips, Printers.

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